



新冠病毒数据分析系列公益讲座 COVID-19 Data Analysis Webinars



第五讲、疫情数据时空特性分析

杨超伟，乔治梅森大学地理和地球科学学院教授

点评人：龚健雅院士，武汉大学遥感信息工程学院院长

主持人：张学良，上海财经大学长三角与长江经济带研究院执行院长

合办单位：上海财经大学长三角与长江经济带研究院

北京时间 2020年5月29日上午9-10点



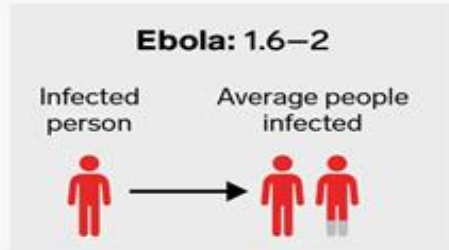
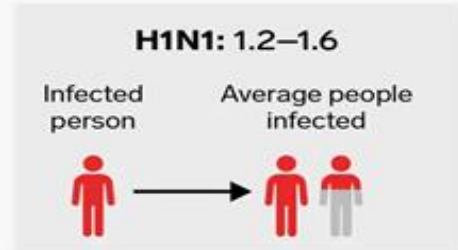
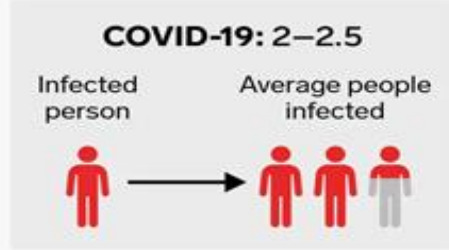
Outline: 提纲

1. Introduction & Background: 研究背景
2. Computing Infrastructure: 计算平台
3. Data Collection & Sharing: 数据收集与共享
4. Spatiotemporal Pattern Analytics: 时空特性分析
5. Summary: 总结
6. Acknowledgements: 致谢



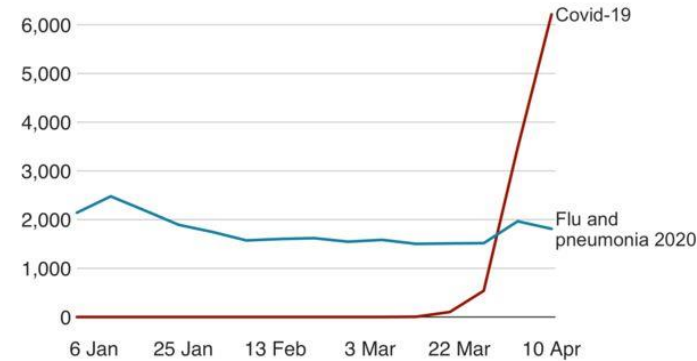
新型冠状病毒梦魇

The average number of people that one person with a virus infects, based on the R_0 scale



Coronavirus deaths spike above flu

Weekly coronavirus deaths compared with flu

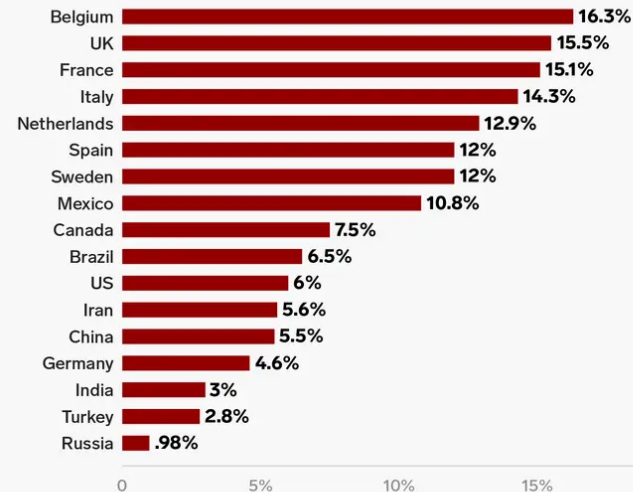


Source: ONS provisional weekly deaths in England and Wales



<https://www.bbc.com/news/health-52361519>

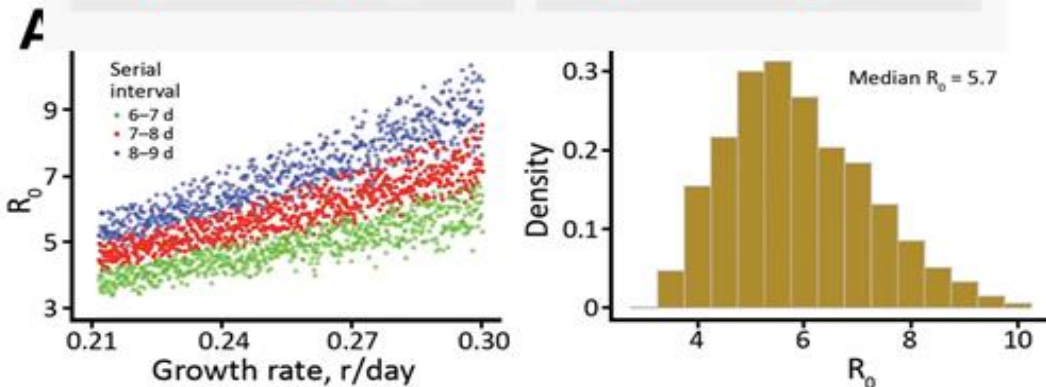
COVID-19 death rates per country



Updated as of May 22, 2020.

Source: Johns Hopkins University dashboard

INSIDER



https://wwwnc.cdc.gov/eid/article/26/7/20-0282_article

时空快速响应

- **STC 任务：建立国家范围乃至国际范围的时空架构**
 - 时空思维-> 人类智慧
 - 时空计算-> 计算工具
 - 时空应用-> 国家、国际范围的重要应用: 新型冠状病毒时空研究 (covid-19)
- **IAB成员支持通过的快速响应项目**
 - 组成国际工作小组
 - IAB 支持
 - NSF快速响应项目
 - 亚马逊云计算支持
 - 国内外的合作



我们应对快速响应的措施

- 近似实时的数据和信息采集
- 提供收集数据的便捷访问
- 整合中心前7年时空分析工具集
- 测试整合来自我们团队的分析方法及开源产品，以及
- 利用弹性时空计算来支持数据分析处理，从而快速生成支持决策和应对的必要信息

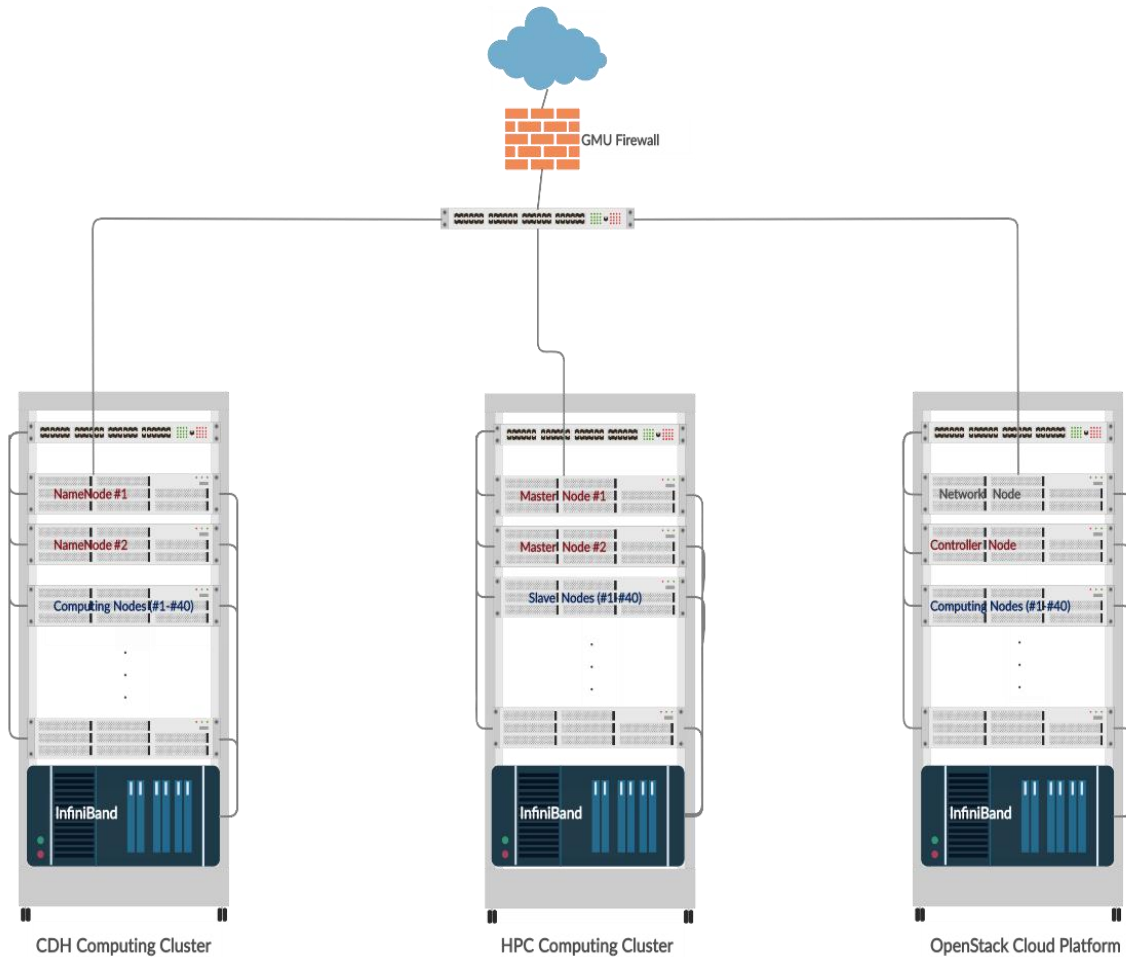


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本地计算资源及架构

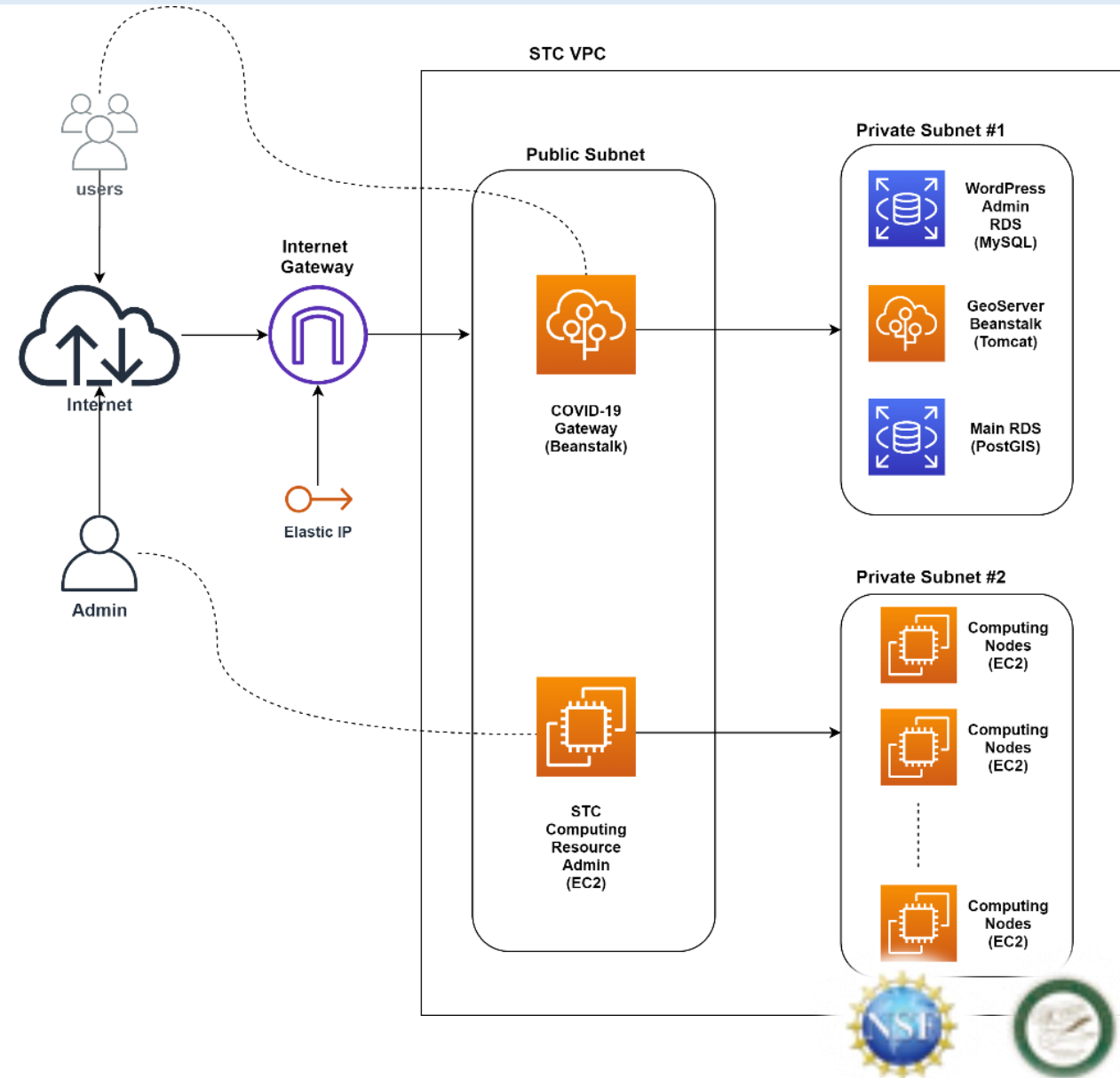


□ 3个应对不同任务独立设计的计算
集群总共拥有 3024 个CPU core:

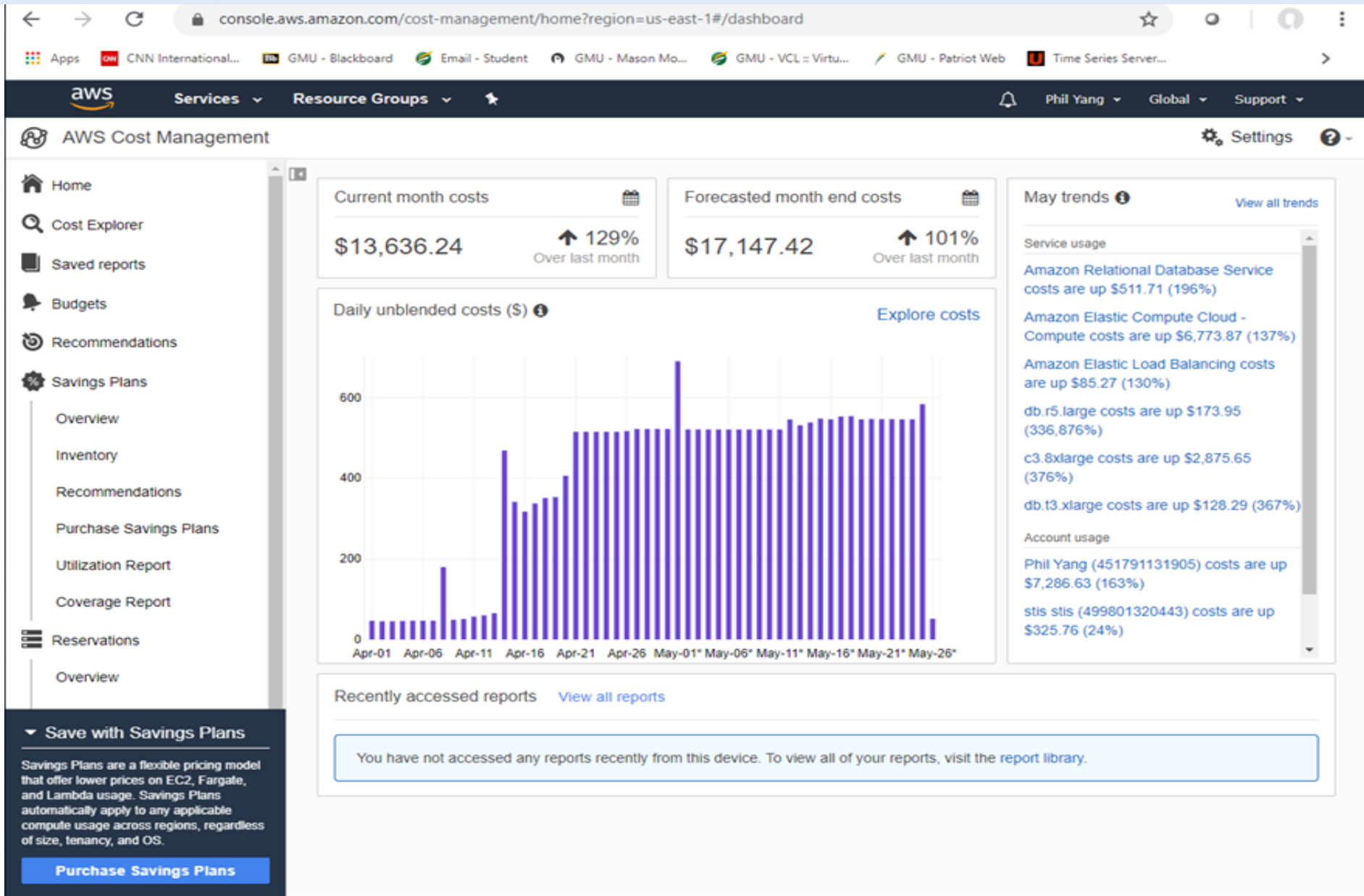
- 基于Hadoop分布式文件系统的云计算平台 (CDH)
- 基于MPI的高性能计算集群 (HPC)
- 基于Openstack的云共享弹性平台 (Cloud)

基于亚马逊云的高可用性应用

- ❑ 通过Beanstalk 和 RDS构建在亚马逊云上的高可用的covid-19 门户网站
- ❑ 应用弹性计算资源支持covid-19相关研究. 例如夜光遥感观测分析
- ❑ 构建了HDFS和YARN的弹性云计算环境以支持基于内存的分布式计算(Spark)



亚马逊公有云使用情况



Save with Savings Plans

Savings Plans are a flexible pricing model that offer lower prices on EC2, Fargate, and Lambda usage. Savings Plans automatically apply to any applicable compute usage across regions, regardless of size, tenancy, and OS.

[Purchase Savings Plans](#)

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COVID-19数据的挑战与目标

□挑战

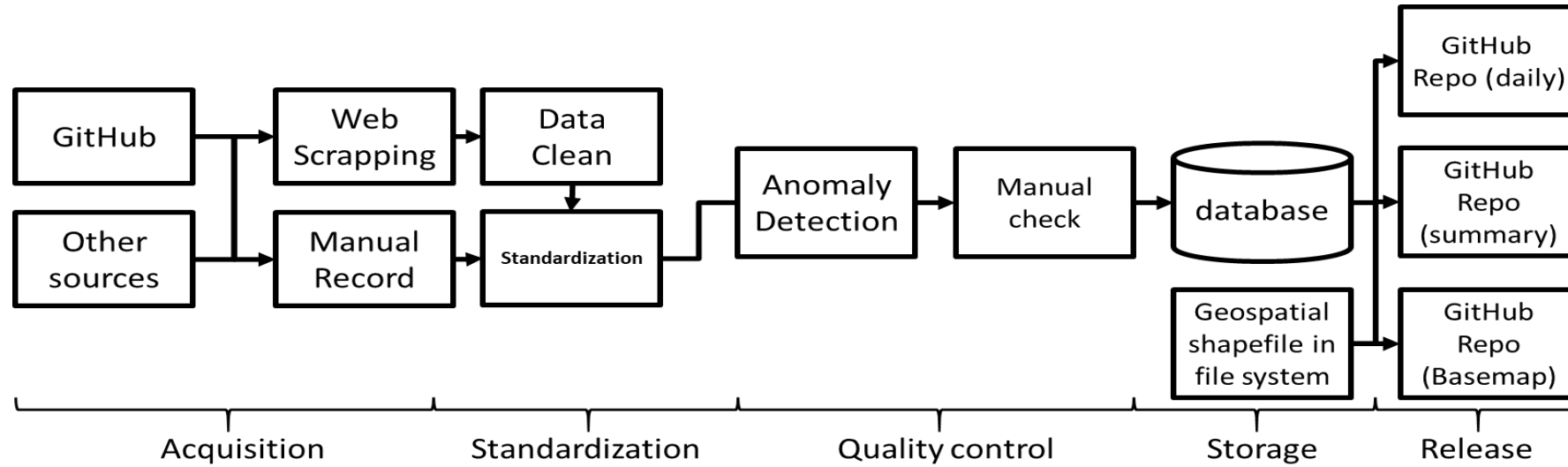
- 。数据来自于很多机构组织，存储和发布非常分散
- 。没有统一的数据标准，异质数据难以对比和相互融合
- 。数据在时间上的持续性不好，长期稳定的有效数据难以获得

□目标

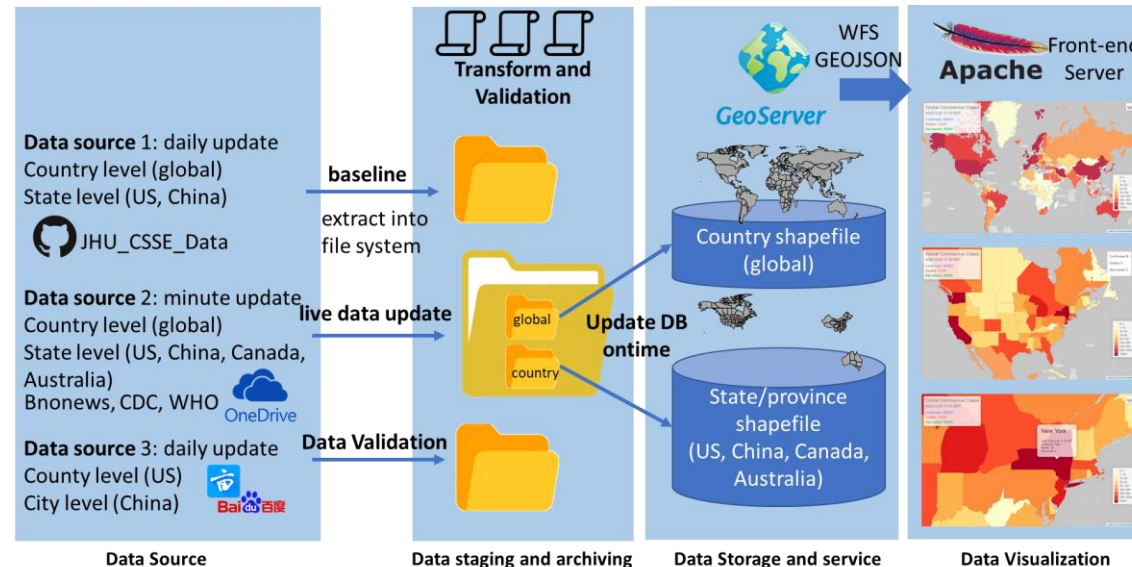
- 。做高质量的时空疫情数据集
- 。整合多源数据
- 。建立在不同空间尺度下的统一数据标准
- 。收集长期有效的数据
- 。以供疫情相关的联合交叉研究



数据工作流程

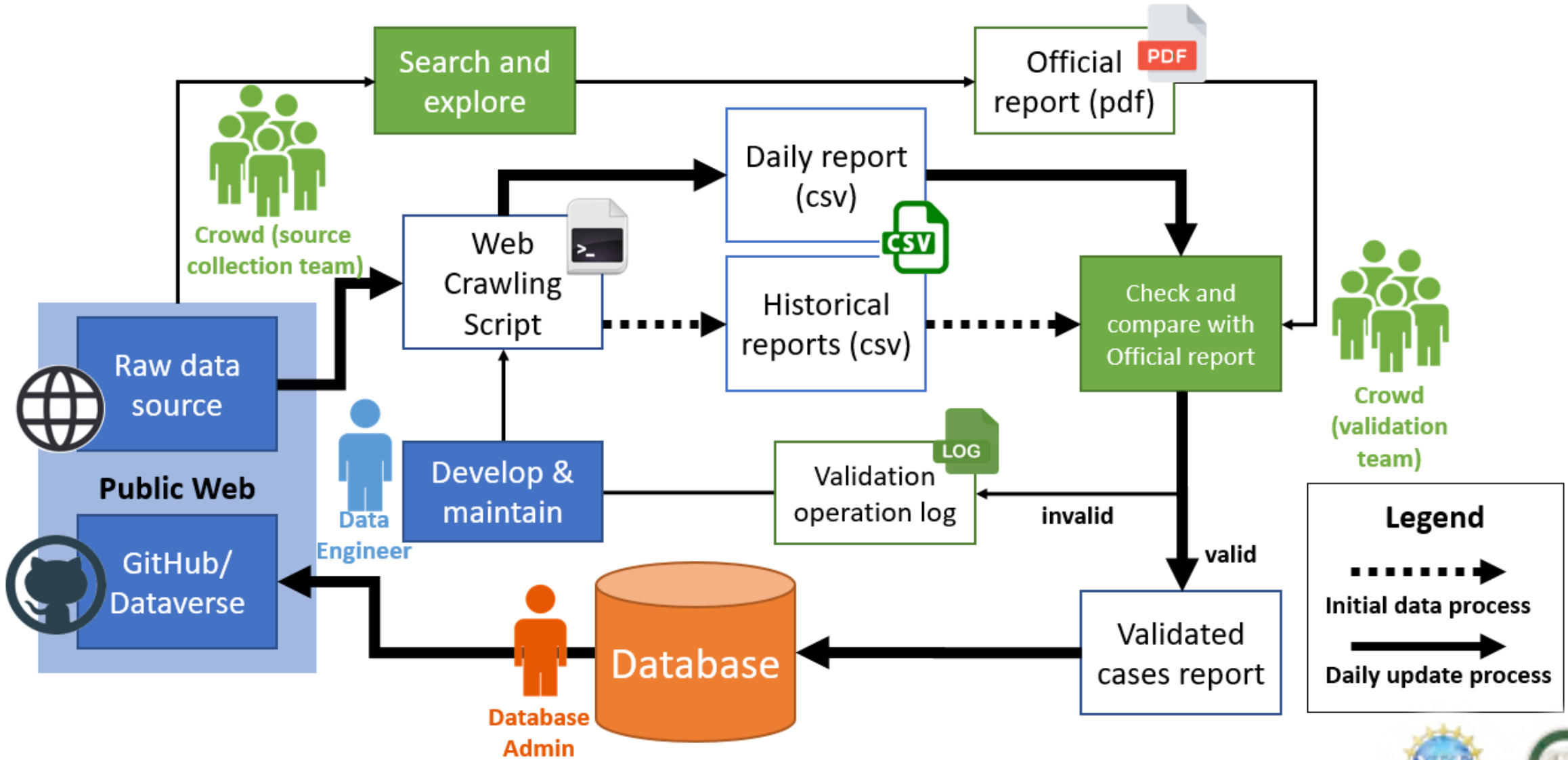


疫情数据处理流程



应用：实时疫情数据展示

基于众包的数据质量控制



GitHub

□ GitHub库地址: <https://github.com/stcenter/COVID-19-Data>

- 按全球/国家组织的病例数据
- 每个国家: 提供每日病例数据和病例时间序列数据

Overall data sources by Country

source data source source validation source

Country / Region	Continent	Admin level	Data Source
Global	Global	0	source Johns Hopkins CSSE source WHO
United States	North America	1, 2	source Johns Hopkins CSSE source USAFACTS source CDC.gov
China	Asia	1	source Ding Xiang Yuan source NHC
Canada	North America	1	source Johns Hopkins CSSE source canada.ca
Australia	Oceania	1	source Johns Hopkins CSSE source health.gov.au
Italy	Europe	1	source protezionecivile.it source worldometers
Germany	Europe	1	source covid19-eu-data source rki.de
Austria	Europe	1	source sozialministerium.at source sozialministerium.at
Brazil	South America	1	source covid.saude.gov.br source covid.saude.gov.br
Chile	South America	1	source Covid-19 Latinoamérica source minsal.cl
Japan	Asia	1	source covid-2019.live source stopcovid.jp
Russia	Europe	1	source yandex.ru source стопкоронавирусы.рф
South Africa	Africa	1	source NICD source health.gov.za source statssa.gov.za
Malaysia	Asia	1	source covid-19-malaysia source covid-19-infoshat.gov.my
Denmark	Europe	1	source covid-19-ssi.dk source coronatracker.com
Finland	Europe	1	source aroge.com source th.fi
Greece	Europe	1	source covid19.gov.gr source eody.gov.gr
Hungary	Europe	1	source koronavirus.gov.hu source abouthungary.hu
Croatia	Europe	1	source koronavirus.hr source worldometers
Iceland	Europe	1	source wikipedia.org source covid.is
Slovakia	Europe	1	source wikipedia.org source korona.gov.sk

Daily data

Daily data provides automatically updated information of COVID-19 cases, and related attributes daily.

Attribute Name	Description	Format	Example
date	The date representing the current day in which the data represents. UTC time is used for this dataset, all values will be calculated before the end of UTC time of the date.	Date (YYYY/MM/DD) in UTC	2020/04/09
country_name	Name of the country.	string	United States
iso3	3 digit ISO country codes.	varchar(3)	USA
admin1_name	The name for admin 1 level.	string	Virginia
hasc1	This will represent the Hierarchical administrative subdivision codes (HASC) for admin 1 level.	string	US.VA (for Virginia, United States)
local_id1	This will represent the ID for specific admin 1 level. ID that represents the country's admin 1 level	string	VA (for Virginia, United States)
confirmed	The number of confirmed cases.	integer	777
death	The number of death cases.	integer	19
recovered	The number of recovered cases. (might be null for admin 2 level)	integer	null
Miscellaneous	Other data attributed to our dataset.	TBD	TBD

Summary data

Summary data records the COVID-19 cases, and related attributes, to show the timeline of cases.

Attribute Name	Description	Format	Example
country_name	Name of the country.	string	"US"
iso3	3 digit ISO country codes.	varchar(3)	USA
admin1_name	The name for admin 1 level.	string	State for USA
date	The date representing the current day in which the data represents. UTC time is used for this dataset, all values will be calculated before the end of UTC time of the date.	UTC	YYYY/MM/DD



新冠数据、信息、知识门户 (Gateway)

COVID-19 Spatiotemporal Rapid Response Gateway

HOME CHRONICLES DATA ACCESS COVID-19 LIVE PUBLICATIONS METHODS AND TOOLS ARCHITECTURE TASK FORCES SETTINGS (PRIVATE)

A Gateway to COVID-19 Data, Information and Knowledge.

- Chronicles
- Data
- COVID-19 Live
- Publications
- Methods & Tools

VIEW DETAILS» VIEW DETAILS» VIEW DETAILS» VIEW DETAILS» VIEW DETAILS»

Developed and operated by NSF Spatiotemporal Innovation Center, and supported by its past/present members include NASA NCCS, ITCD, DOS, NOAA, USGS, United Nations, NGCC, ZJCH, RMDS, NASMG, Northrop Grumman, CDL, OmniSci, SIEMENS, SHASM.

<https://covid-19.stcenter.net/>

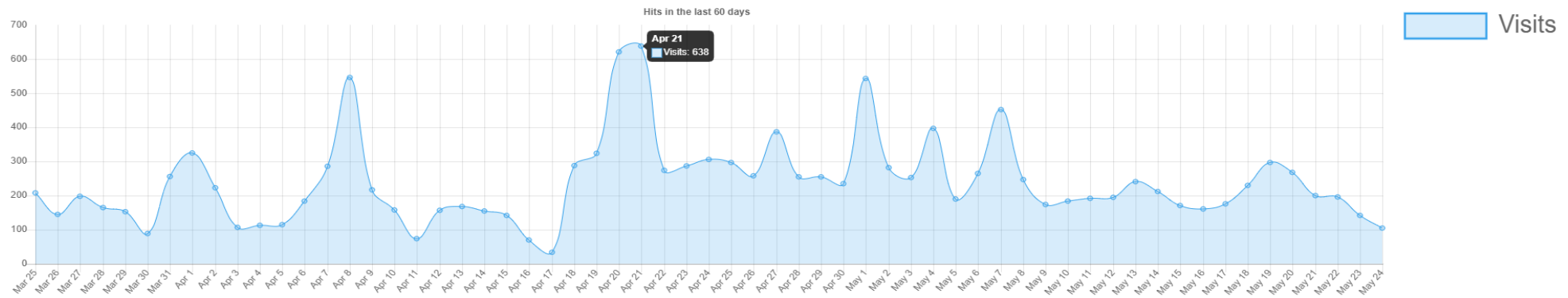


COVID-19 Gateway

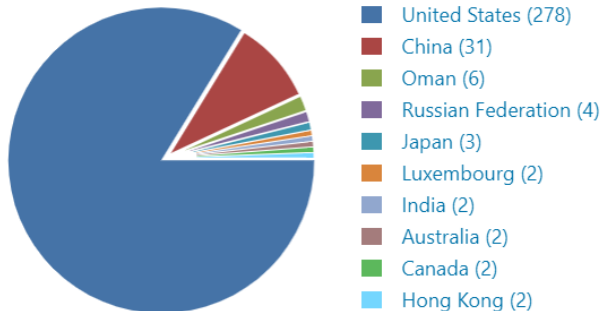


Index	value
Visitors in 30 days	596
Visit in 30 days	7492
Total visit from start	16766

Hits Statistics Chart

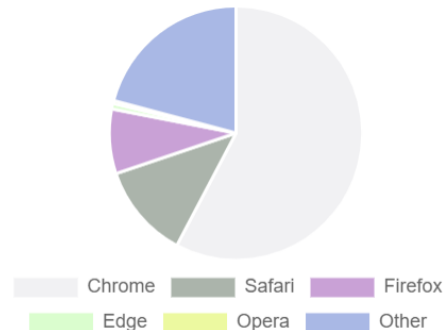


Top 10 countries



Top 10 countries for visitors

Browsers



Top browsers for visitors

Top Pages

ID	Title	Link	Visits
1	Home Page	/	5,620
2	Data Collection	/index.php/data-access/	501
3	COVID-19 Live Map	/index.php/covid19-livemap/	371
4	Publication Analytics	/index.php/publication-analysis/	275
5	News Timeline	/index.php/chronicle/	234
6	Methods and Tools	/index.php/methods/	194
7	Home Page	/index.php	157
8	Task Forces	/index.php/task-forces/	105
9	Architecture	/index.php/architecture/	99
10	-	/index.php/login/	62

Top visit pages in last 30 days



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疫情大事记


REUTERS Business Markets World Politics TV More

WORLD NEWS MAY 22, 2020 / 10:41 PM / A DAY AGO

Exclusive: U.S. accuses China of blocking U.S. flights, demands action

David Shepardson 4 MIN READ


WASHINGTON (Reuters) - The U.S. government late on Friday accused the Chinese government of making it impossible for U.S. airlines to resume service to China and ordered four Chinese air carriers to file flight schedules with the U.S. government.



health Food Fitness Wellness Parenting Vital Signs

Large study finds drug Trump touted for Covid-19 is linked to greater risk of death and heart arrhythmia

By Jamie Gumbrecht and Elizabeth Cohen, CNN
 Updated 2:05 PM ET, Fri May 22, 2020



Trump's history of promoting hydroxychloroquine 01:47

(CNN) — Seriously ill Covid-19 patients who were treated with hydroxychloroquine or chloroquine were more likely to die or develop dangerous irregular heart rhythms, according to a large observational study published Friday in the medical journal *The Lancet*.

President Donald Trump has been a frequent cheerleader for a combination of the antimalarial hydroxychloroquine and the antibiotic azithromycin as a Covid-19 treatment. He promoted the drugs nearly 50 times, despite pleas from scientists to let studies decide if the treatment worked

COVID-19 Chronicle

May 23, 2020

- New York coronavirus fatalities fall to lowest level since March
<https://www.theverge.com/2020/4/24/21234936/amazon-wage-increase-warehouse-worker-coronavirus-covid>
- Exclusive: U.S. accuses China of blocking U.S. flights, demands action
<https://www.forbes.com/sites/robertfarrington/2020/05/12/2020-2021-federal-student-loan-rates-drop-to-record-lows/#3df3095a1344>

May 23, 2020

May 22, 2020

- TSA prepared for summer travelers with updated security procedures
<https://www.theverge.com/2020/4/24/21234936/amazon-wage-increase-warehouse-worker-coronavirus-covid>
- Large study finds drug Trump touted for Covid-19 is linked to greater risk of death and heart arrhythmia
<https://www.forbes.com/sites/robertfarrington/2020/05/12/2020-2021-federal-student-loan-rates-drop-to-record-lows/#3df3095a1344>

May 21, 2020

- As Global Economy Fears the Upcoming Recession, Travel Is Already

CNBC BUSINESS INVESTING TECH POLITICS CNBC TV

New York coronavirus fatalities fall to lowest level since March

Published Sat, May 23, 2020 at 9:31 PM EDT
 Emma Newburger

KEY POINTS

- Coronavirus deaths in New York state have fallen below 100, Gov. Andrew Cuomo said on Saturday, marking the lowest daily death toll from the virus since March 26.
- The governor said the 84 new reported deaths was a "tragedy" but that the downward trend in daily deaths was a sign that the state is making significant progress.
- Cuomo said that the mid-Hudson region will reopen starting on Tuesday and Long Island will reopen on Wednesday as part of the state's Phase 1 plan.

TRENDING NOW

- China will likely face U.S. sanctions over Hong Kong national security law, White House says
- Brain coach used by Elon Musk's SpaceX, 3 tips to learn anything faster
- Ohio GOP governor calls for public to wear masks "This is not about whether you're left or right"
- Flying during the pandemic? Here's what you need to know

Transportation Security Administration

TSA prepared for summer travelers with updated security procedures

In response to COVID-19, procedural changes rolling out nationwide by mid-June

National Press Release
 Thursday, May 21, 2020

WASHINGTON — With the Memorial Day holiday weekend kicking off the start of summer, the Transportation Security Administration is preparing a pandemic. TSA has implemented changes to the security screening process that reduce the potential for cross-contamination at the security check. TSA has already begun implementation of other changes — such as masks to be implemented at airport checkpoints — to reduce risk.

"In the interest of TSA frontline workers and traveler health, TSA is committed to making gradual changes to our screening processes to safely, as much as possible," said TSA Administrator David Perdue. "We continue to evaluate our security measures with an eye toward making smart, timely decisions to ensure."

Over the past couple of weeks, TSA has experienced a steady growth of travelers coming through airport checkpoints. As procedural changes begin, keep possession of their boarding passes. Instead of handing their boarding pass to a TSA officer at the travel document podium, travelers should keep the boarding pass reader themselves. After scanning, travelers should hold their boarding pass toward the TSA officer to allow the officer to read it, rather than a screener's hand passing the boarding pass to the next workstation.

Separate food for bag screening. Passengers should place their carry-on food items into a clear plastic bag and place that bag into a bin. Food is inspected by the bin from the carry-on bag to the bin, so that a TSA officer will need to open the carry-on bag and remove the food items to inspect. This is not the case for the officer's hand to touch a person's container of food and reduce potential for cross-contamination. TSA officers should not touch the food.

Peak smart. Passengers should take extra care to ensure that they do not have any prohibited items, such as liquids, gels or aerosols in quantities over 3.4 ounces. In response to COVID-19, TSA is allowing one quart-sized container containing up to 12 ounces per container. In any case, help to the carry-on bag before being screened for screening. A bag is brought to the screening point, passengers may be directed to screening. This is to ensure the security and safety of the line. The screening point will be directed back to a variety of screening points, including the screening point.

Press Release

As Global Economy Fears the Upcoming Recession, Travel Is Already in a Depression

Published: May 21, 2020 at 12:48 p.m. ET

The MarketWatch News Department was not involved in the creation of this content.

May 21, 2020 (IAM Newswire via COMTEX) — Unemployed rates are now twice that of 1932. At least eight million of the 15.6 million travel-related workforce that existed in the US just three months ago have evaporated into thin air. The conditions are among the companies which received billions of dollars of financial aid under the condition that they not fire any workers before October 1 but things are bound to get worse once this requirement expires.

Airlines

Delta Air Lines (NYSE:DAL) said it will have a surplus of 7,000 pilots by the end of the year if it does not furlough any of its 14,500 pilots. Same is true for all of the industry's Big Three, American Airlines Group Inc (NASDAQ:AAL) and United Airlines Holding (NASDAQ:UAL). Smaller conventional carriers like Alaska (NYSE:ALK) and giant discounter Southwest Airlines Co (NYSE:LUV) are in the same boat, although the situation isn't the same in percentage terms like with the Big Three. Neither of them is as lucky as Apple (NASDAQ:AAPL) which is able to cover six years of expenses.

News Source:
 CNN, CNBC, FOX News, New York Times, Los Angeles Times,
 Washington Post, The Hill, Reuters, Washington Business Journal,
 Bloomberg, etc.



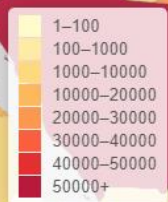
当前全球疫情状态

COVID-19 Spatiotemporal Rapid Response Gateway

HOME CHRONICLES DATAACCESS COVID-19 LIVE PUBLICATIONS METHODS AND TOOLS ARCHITECTURE TASK FORCES SETTINGS (PRIVATE)

Global Coronavirus Cases
2020-5-24 16:44 EDT
Confirmed: 5450278
Deaths: 345494
Recovered: 2261631

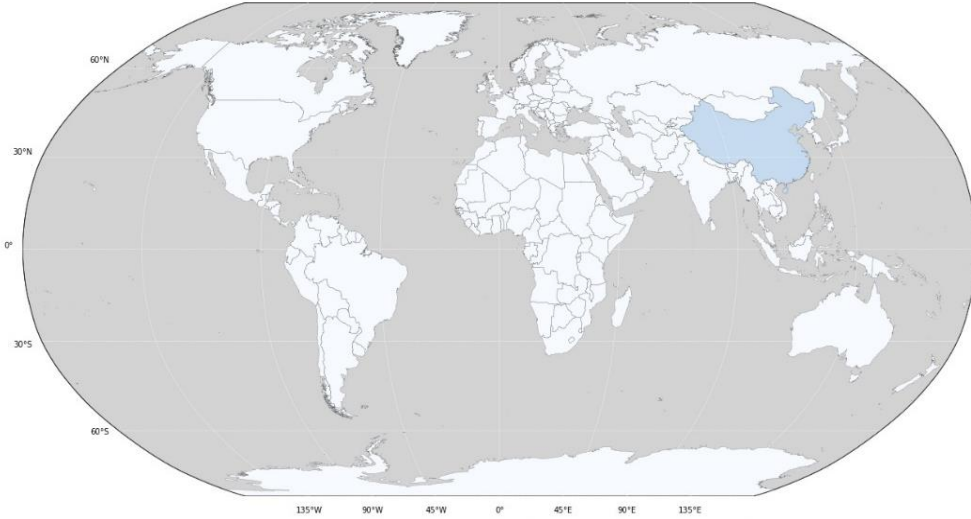
Virginia
Time: 2020-5-24 16:44 EDT
Confirmed: 35749
Deaths: 1159
Recovered: 5047



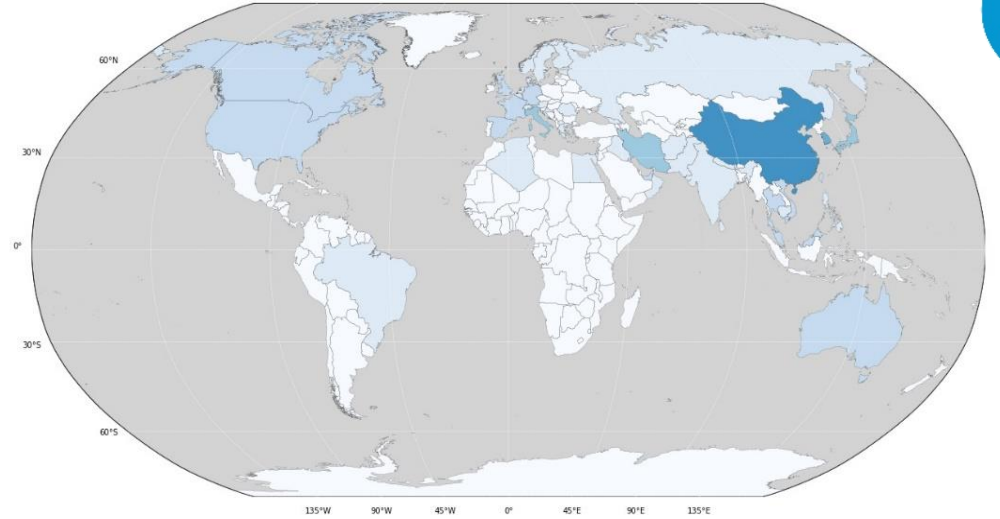
病毒是如何在全球传播的？



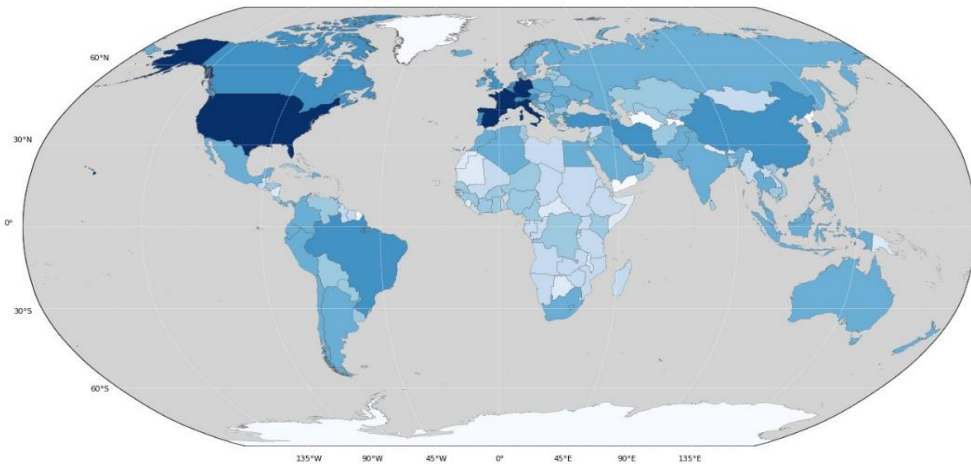
01/17/2020



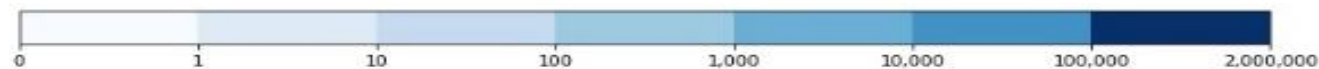
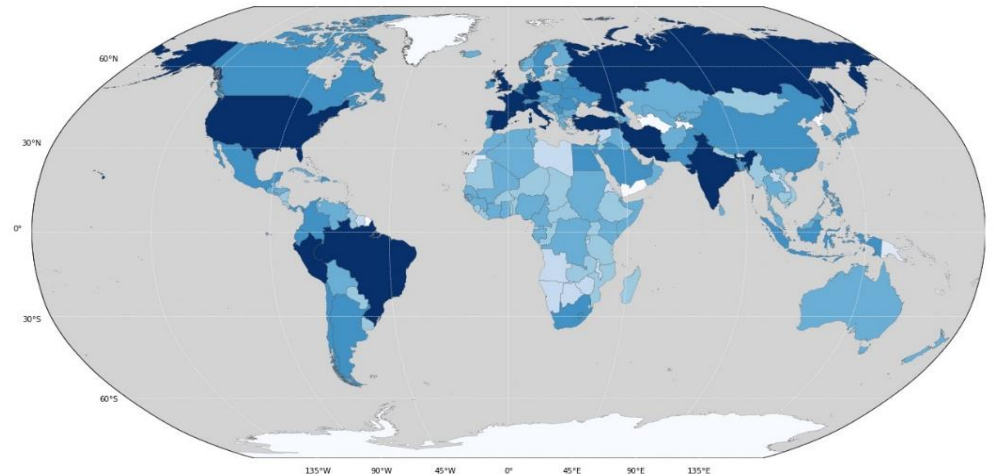
02/27/2020



04/07/2020



05/23/2020



病毒是如何在美国传播的？



(a) 2020-01-23



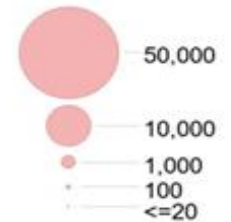
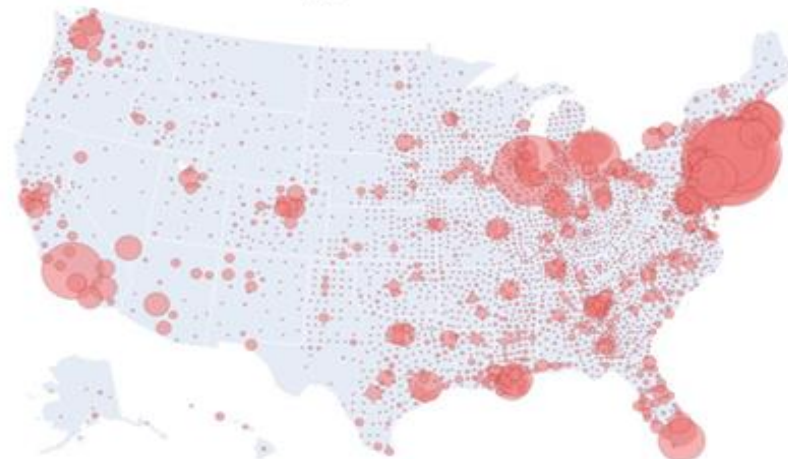
(b) 2020-02-26



(c) 2020-03-17



(d) 2020-04-25



政府与组织对疫情的措施

许多国家都采取了**边境管制**和**封锁措施**，以控制COVID-19的扩散

□政策严厉指数:

NSF 时空创新中心从全球资源收集，处理和可视化的数据

□全球政策严厉指数变化：

一月至四月的全球政策严厉指数正在增加，并且与疫情传播密切相关

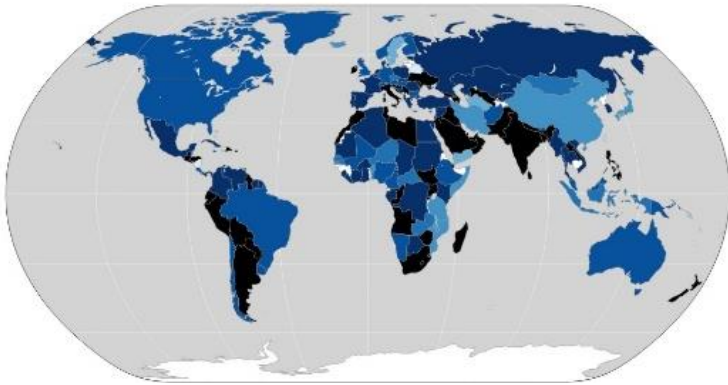
□美国政策严厉指数变化：

美国政策严厉指数从三月初到四月下旬所有增长，并且与疫情传播密切相关



不同国家的政策严格程度

01/01/2020



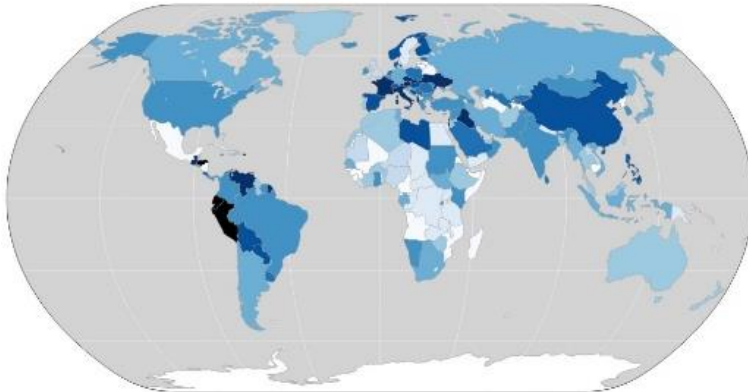
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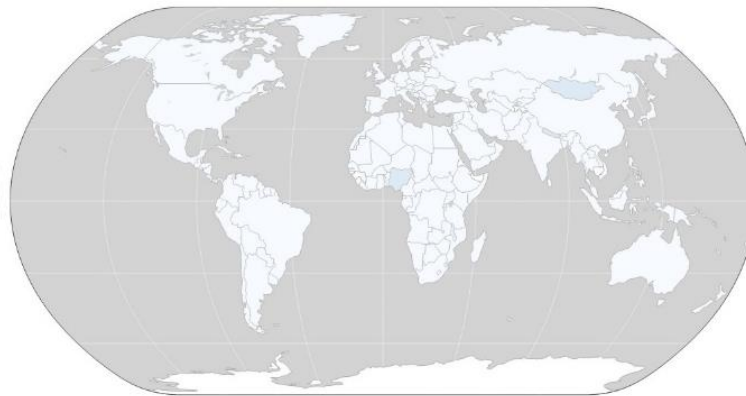
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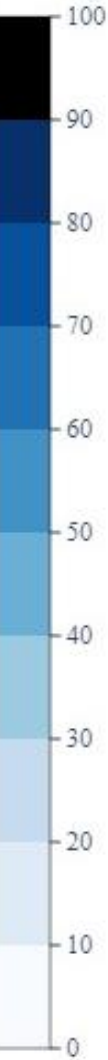
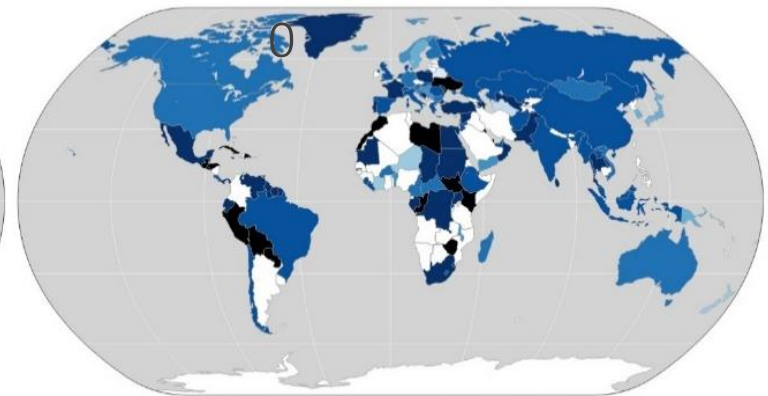
03/17/2020



04/17/2020



05/17/2020

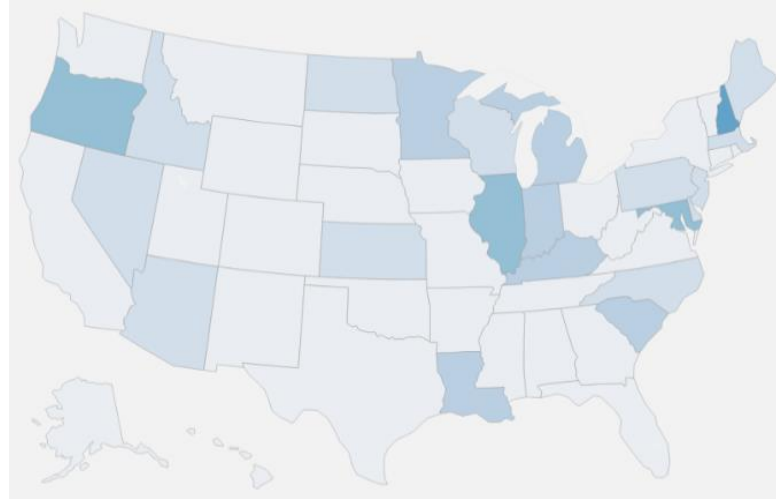


不同州的政策严格程度

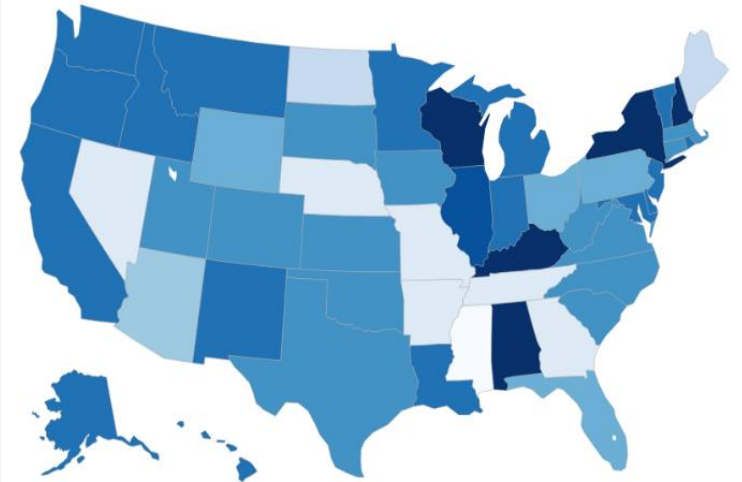
03/05/2020



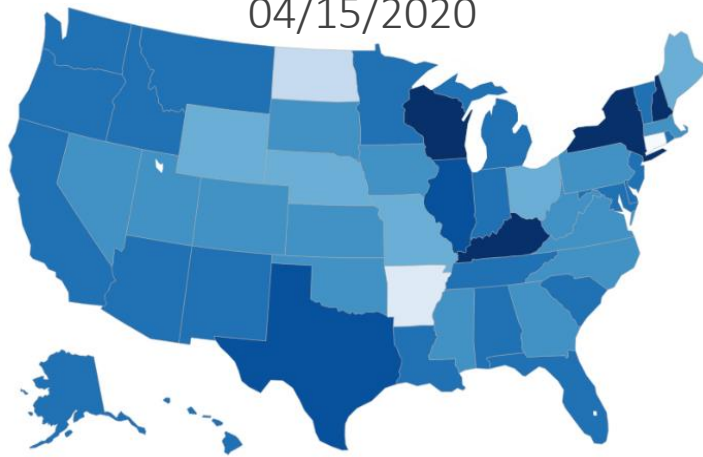
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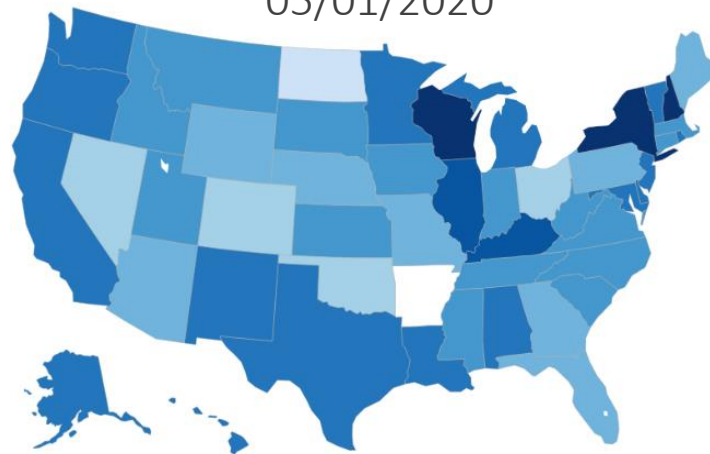
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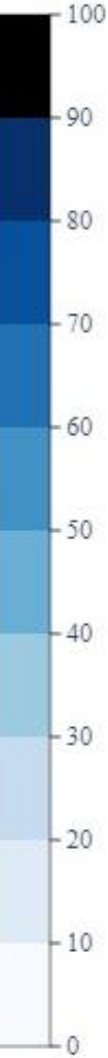
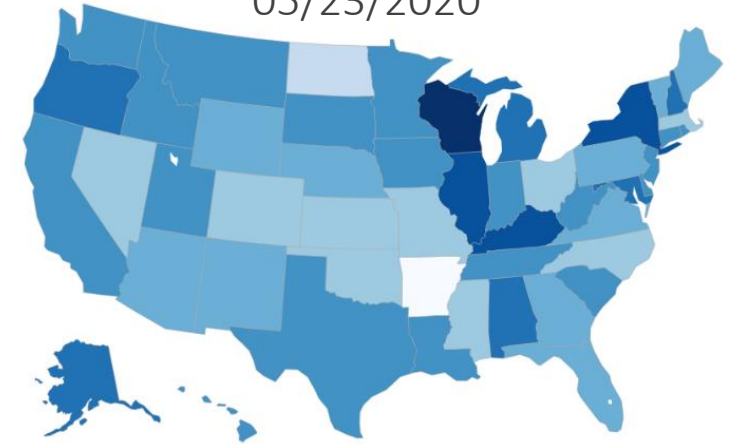
04/15/2020



05/01/2020



05/23/2020

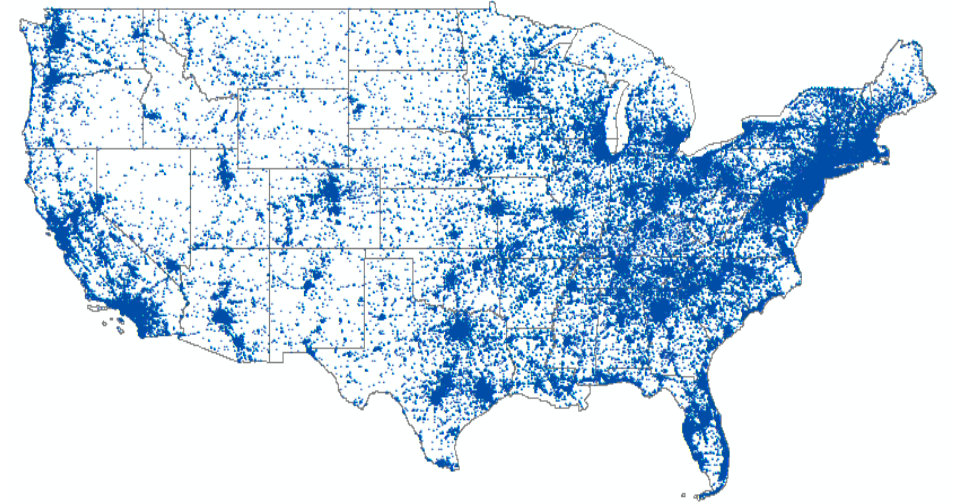


疫情如何影响人员流动？

人员流动影响疫情扩散

□ 社交媒体数据：带地理坐标的推文

从Twitter收集的带GPS地理位置的推文



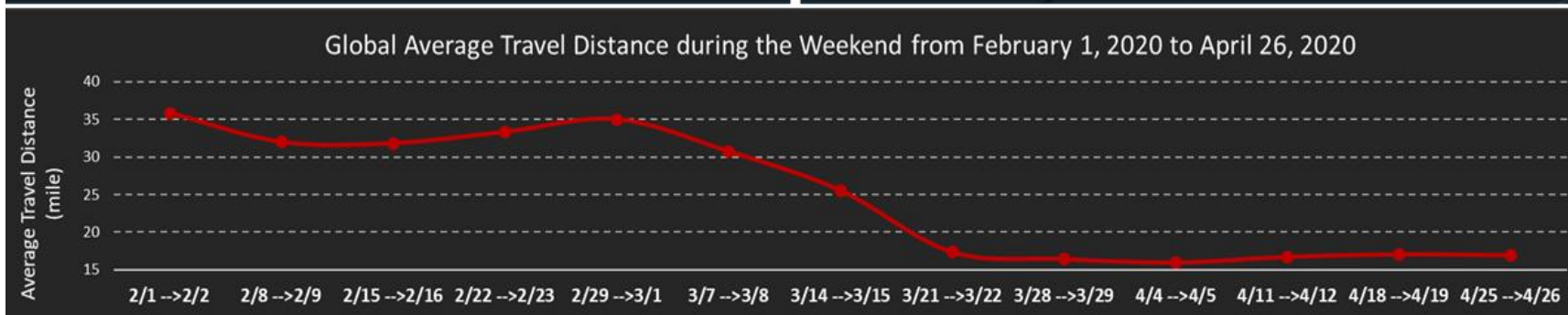
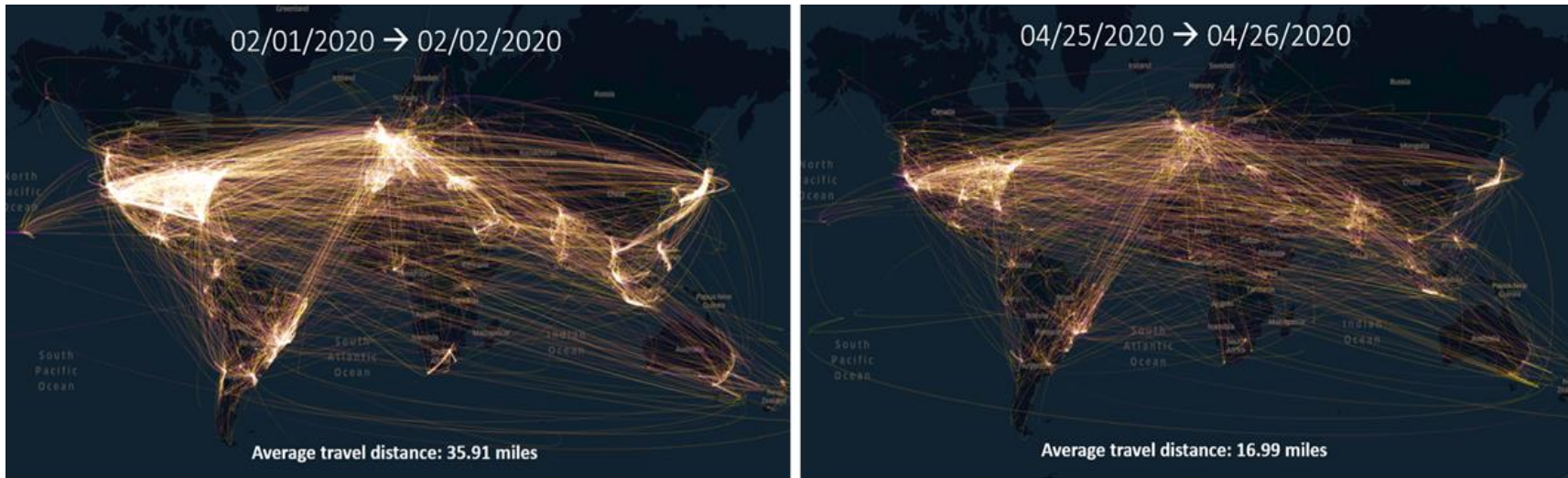
Geo-tweets in March

□ 手机数据：社区流动性报告

由Google收集和汇总，数据记录了不同类别地点（例如零售和娱乐场所，杂货店和药房，公园，公交车站，工作场所和住宅）的人员流动随时间变化的趋势

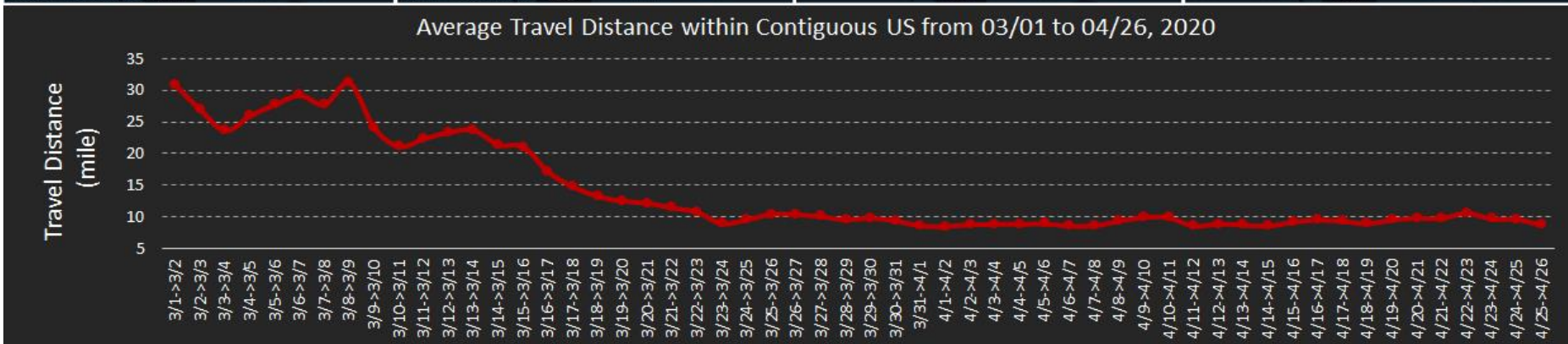
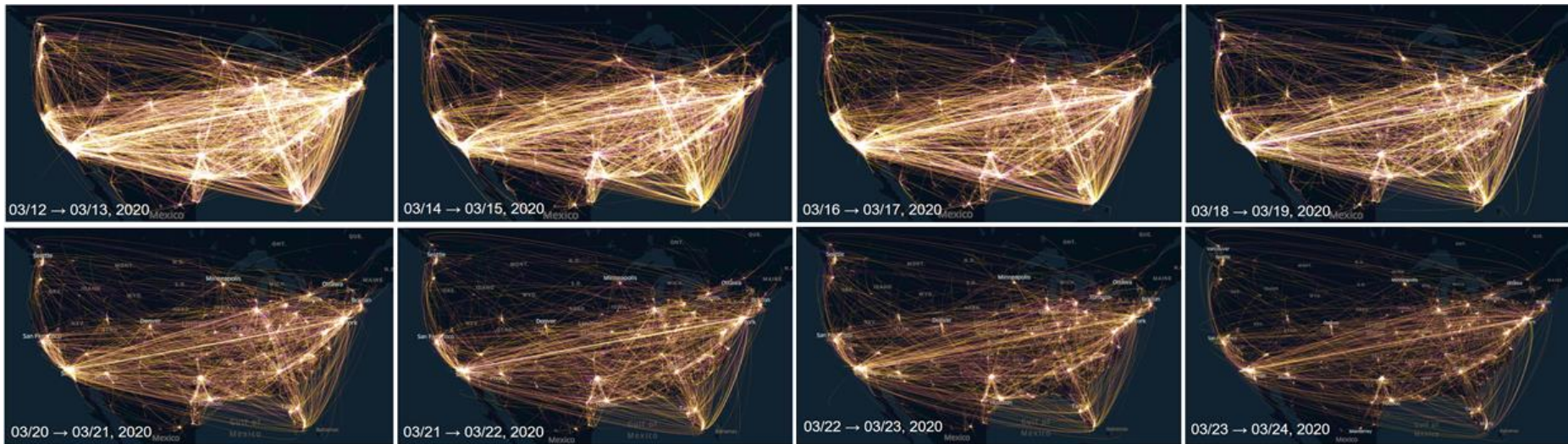
全球范围内的人员流动变化

□ **Geotagged Tweets:** global average travel distance during the weekend from 02/01/2020 to 04/26/2020



美国人员流动变化

□ **Geotagged Tweets:** Population movements before and after the lockdown in the contiguous US.

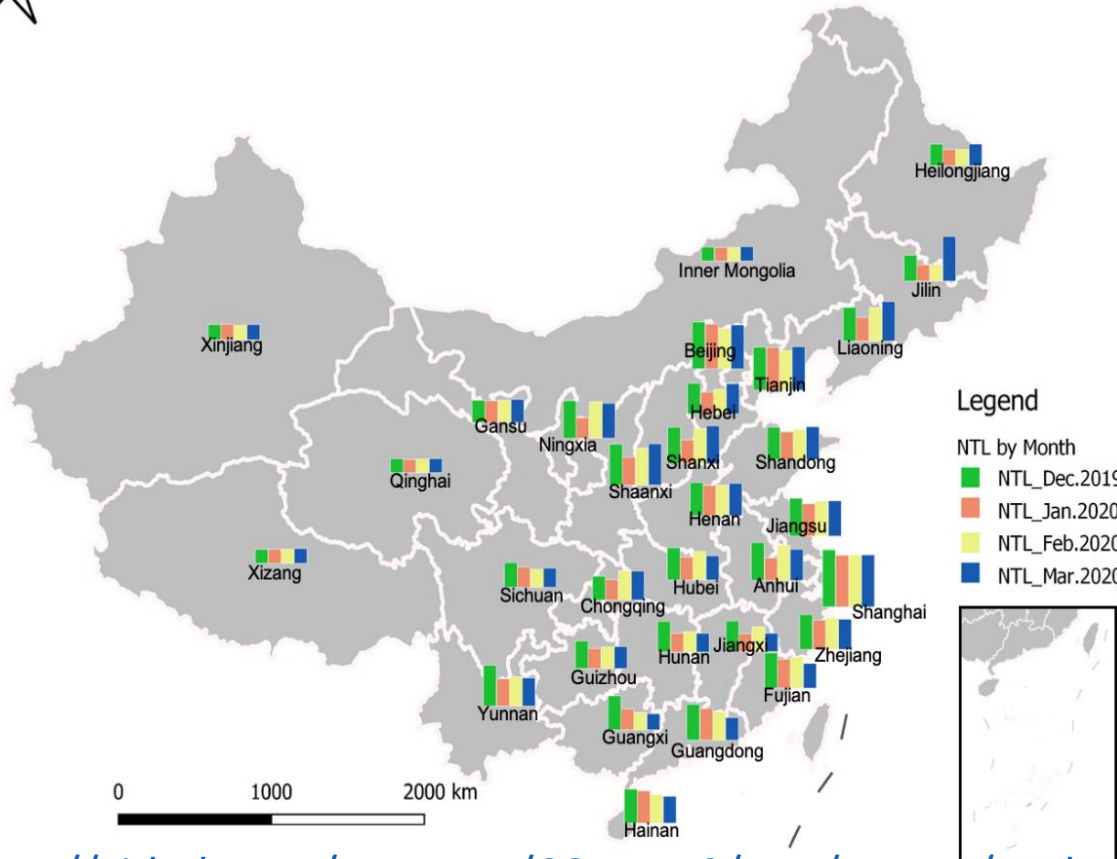


光污染的变化

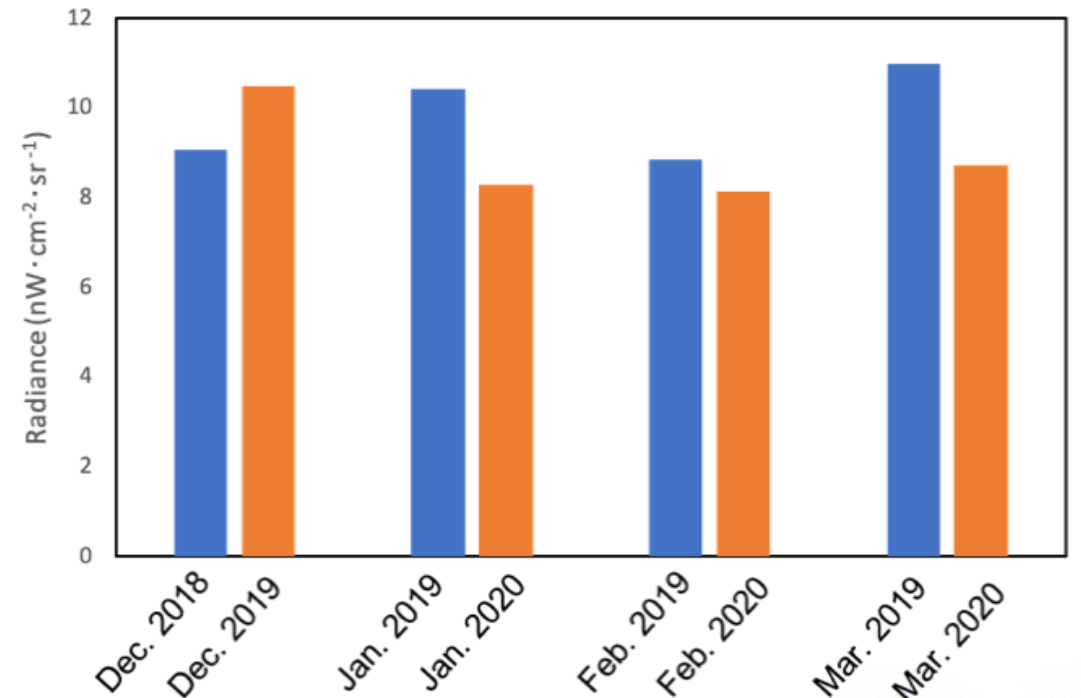
1. 2019年12月至2020年2月，由于疫情蔓延和隔离政策，夜间光照辐射强度呈下降趋势，并且随着各个地方的重新开放，在2020年3月有小幅回升
2. 2020年初的平均夜间光照强度低于2019年同时期。



Monthly Average NTL Radiance of Each Province in China during the Pandemic

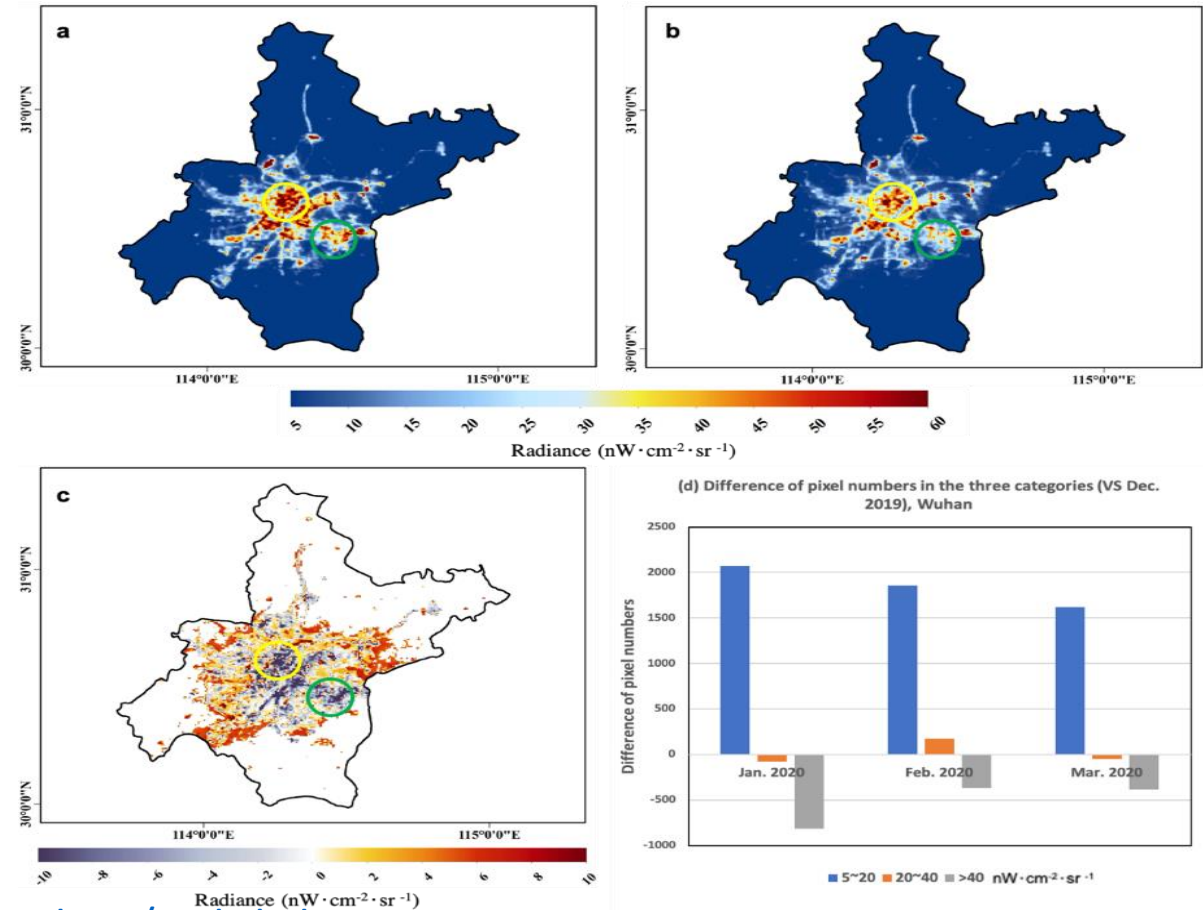
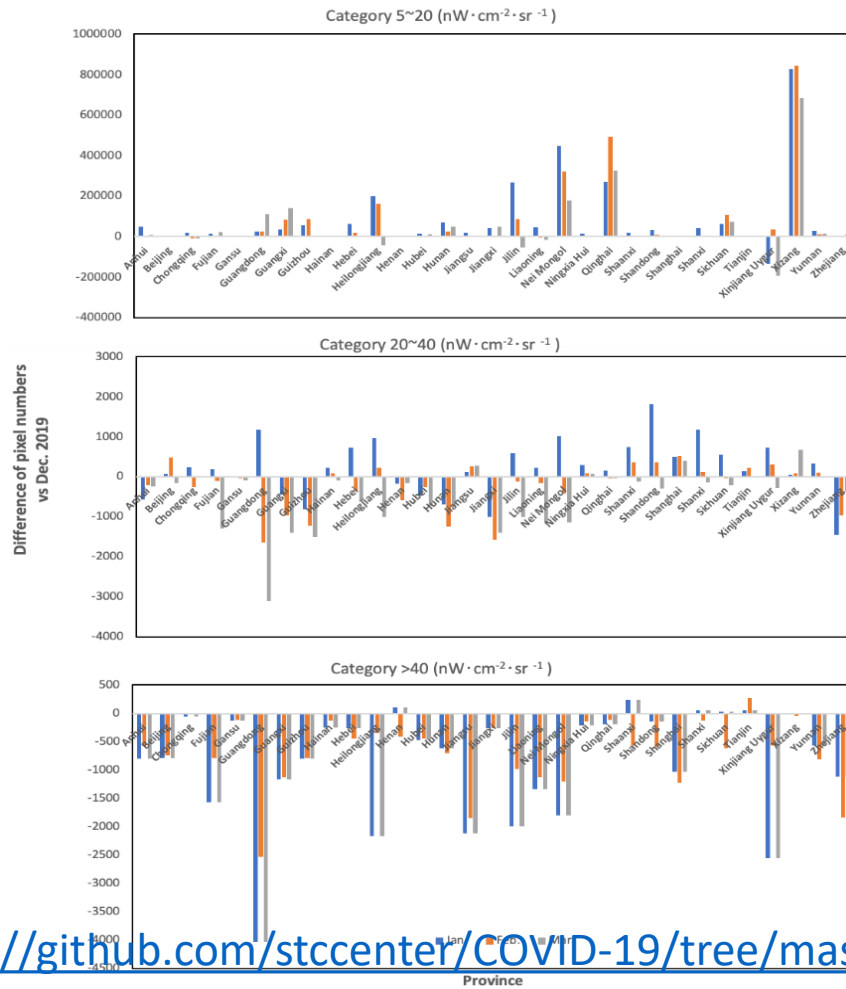


Monthly Average NTL of Mainland China



光污染的变化

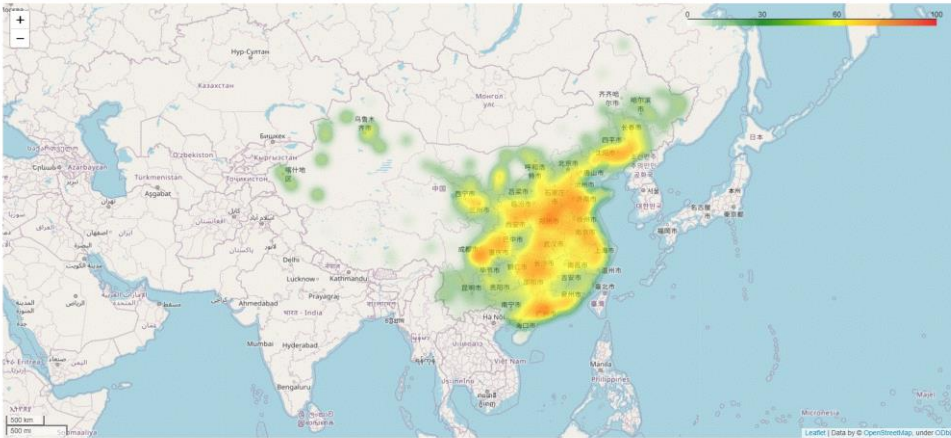
- 不同区域的夜间光照像素个数呈不同变化趋势：居民区像素个数在疫情期间与之前相比有所增加，商业中心像素个数有所减少；
- 武汉市夜间光照在新冠病毒暴发期间与之前相比强度较弱。



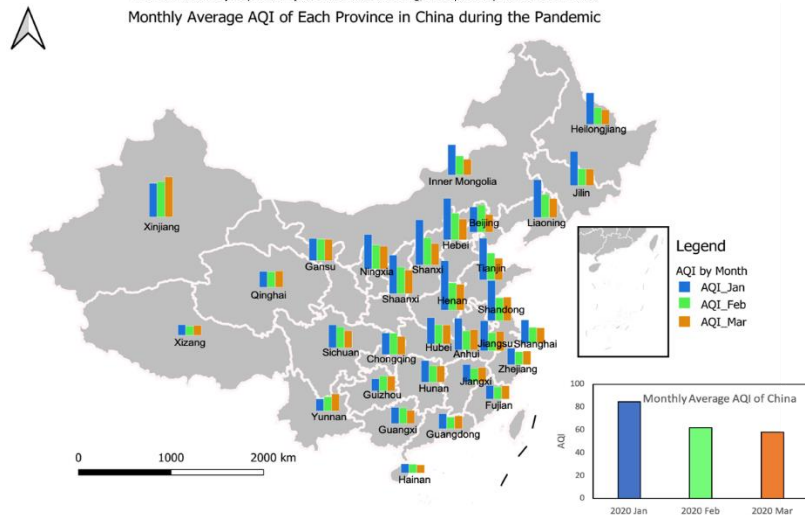
空气质量的變化

- 空气污染指数以及二氧化氮浓度在疫情期间与之前和之后相比均有所减弱；
- 日均空气污染指数在疫情期间呈下降趋势

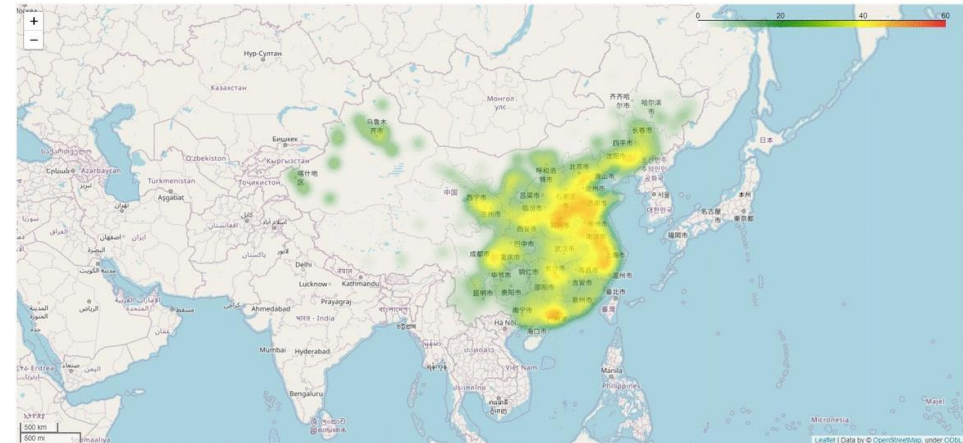
Heatmap of the Air Quality Index on Jan. 01, 2020



Data and visual analytics provided by Qian Liu and Zhiran Zhang, NSF Spatiotemporal Innovation Center.
Monthly Average AQI of Each Province in China during the Pandemic

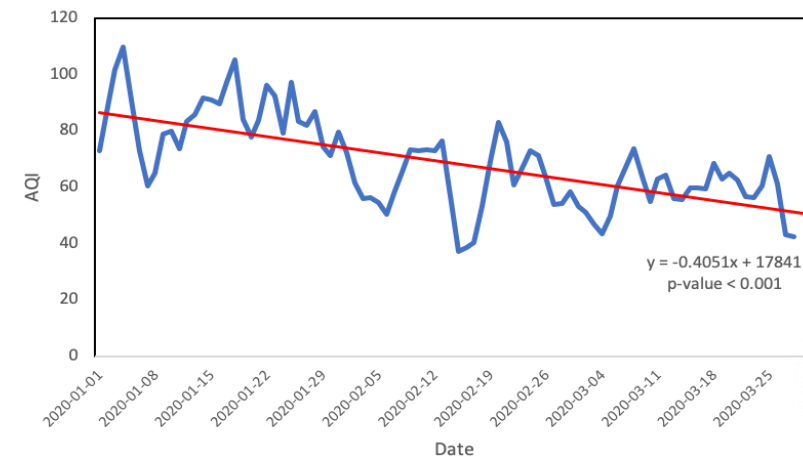


Heatmap of the NO2 Emission on Jan. 01, 2020



Data and visual analytics provided by Qian Liu and Zhiran Zhang, NSF Spatiotemporal Innovation Center.

China AQI trend before and during the COVID-19



新冠病毒研究的进展

问题

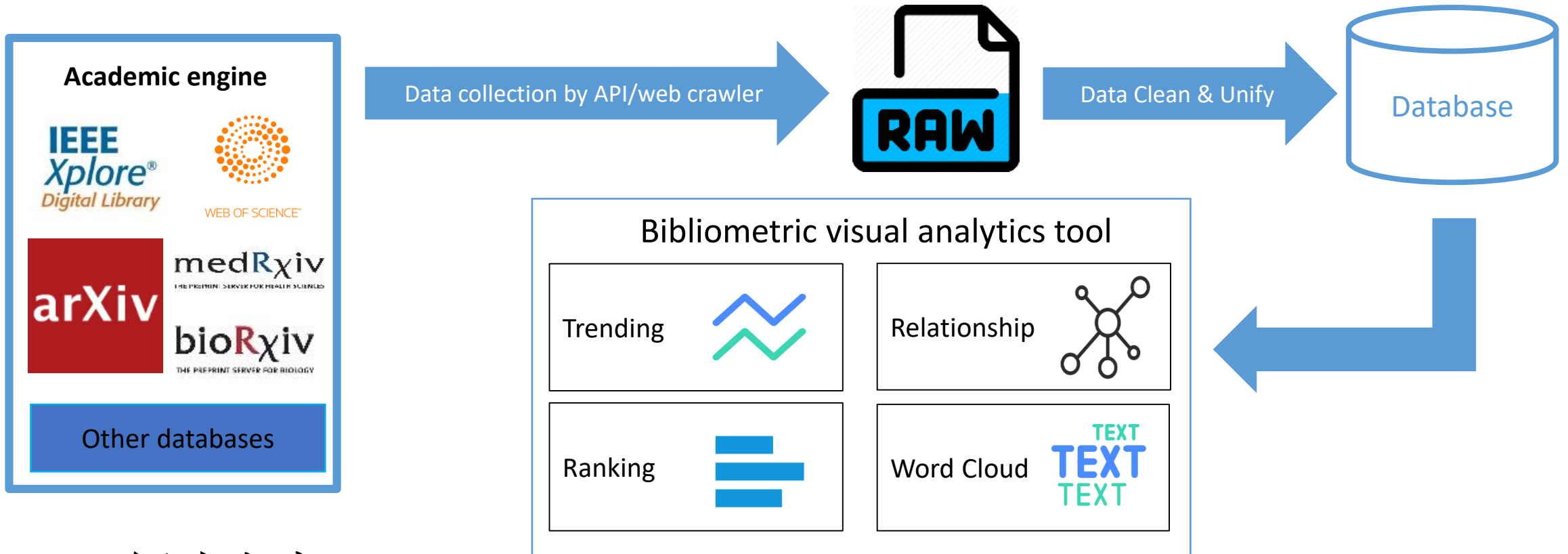
- 大量COVID-19相关的文献
- 相关文献分散在各个学术数据库里
- 每个数据库的数据标准不同
- 整合同领域的所有文献相对困难
- 还未有很好的可视化工具来展示某个领域所有文献的趋势和之间的关系等

目标

- 从各个数据源收集文献数据
- 统一数据标准，存入数据库
- 开发可视化工具来展示文献之间的内在逻辑结构



新冠病毒研究知识库



解决方案

- 从各个学术数据库收集并整合文献数据
- 清理数据，并对数据进行统一化
- 储存进数据库
- 提供文献分析模块来可视化文献的变化与关联
- 用更直观的图表展示文献的核心信息

新冠病毒研究的现状

Search

Trend

Publication

Nation

Institute

Relationship

Nations

Institutes

Authors

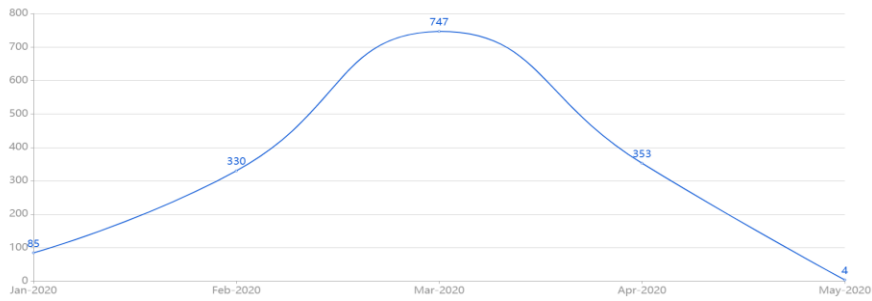
Ranking

Keyword

Institute

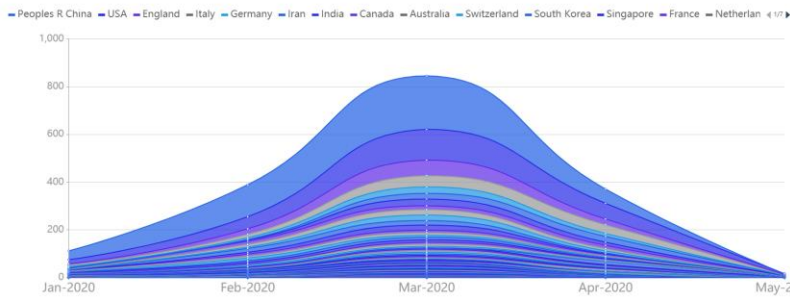
References

Publication Number Changes by Month



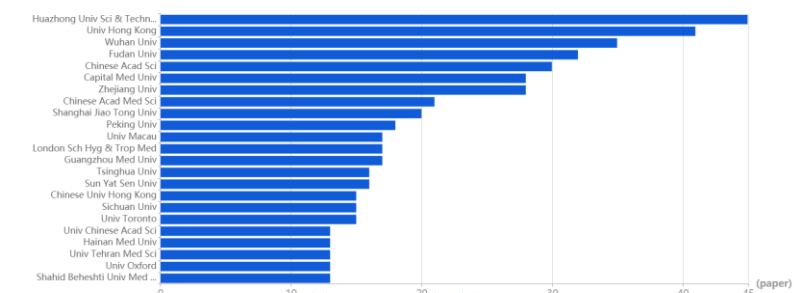
文章发布数量趋势

Contribution of Nations by Month



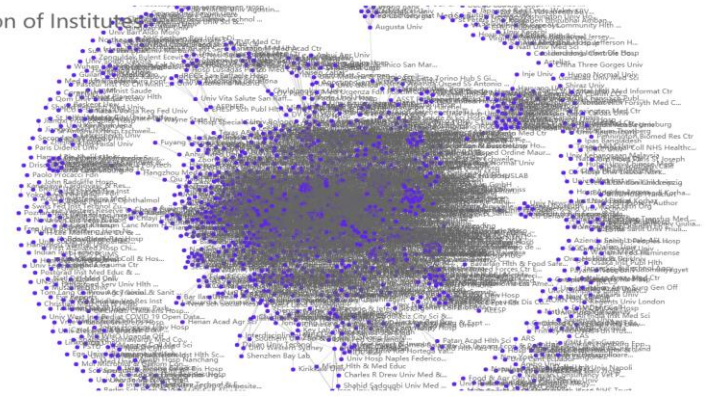
各国文章数趋势

Contribution of Institutes

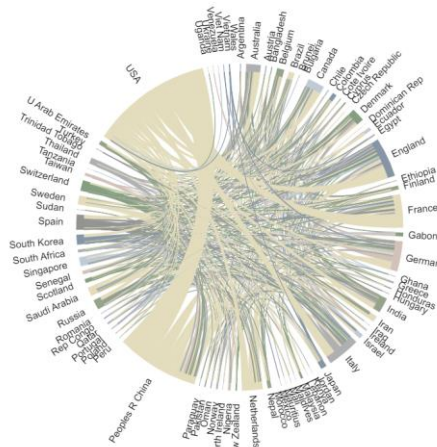


结构贡献度排名

Collaboration of Institutes



研究者与机构的合作情况



国家间的合作情况



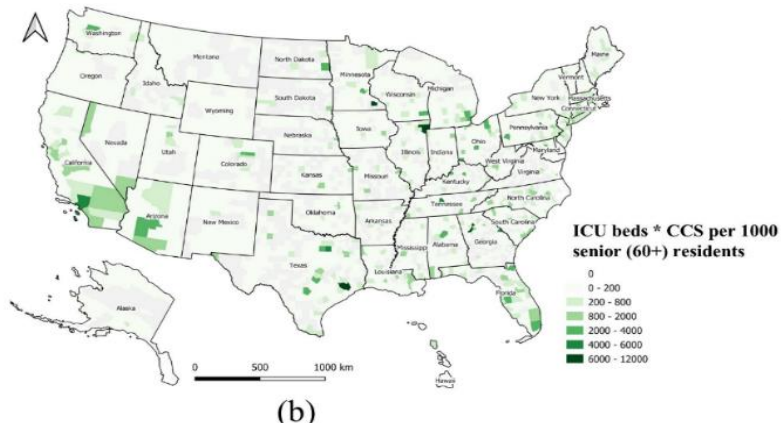
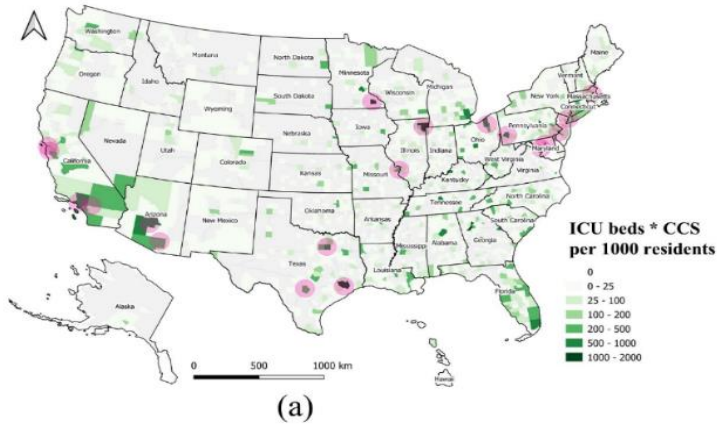
关键词词云分析



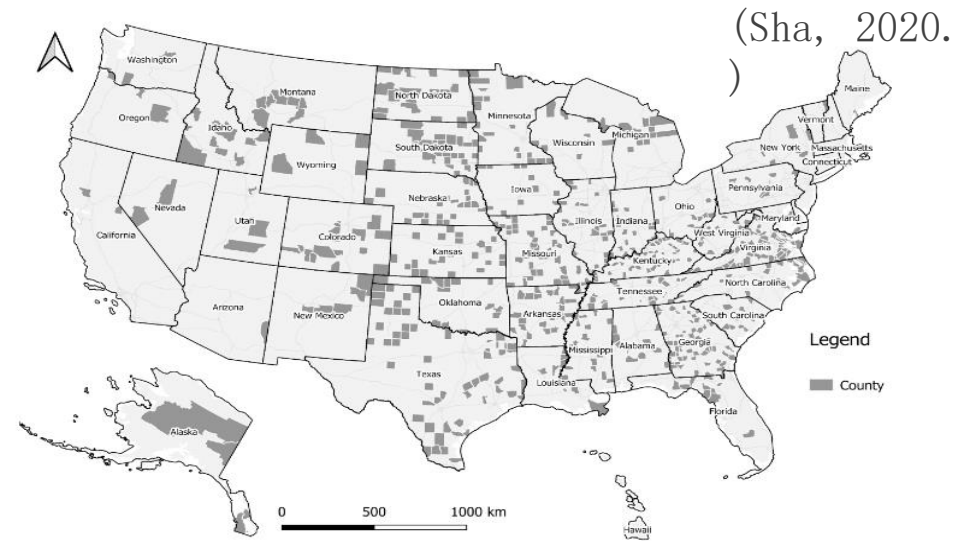
美国的公卫系统承载力如何？

通过对基本医疗软硬件病床和医护人员的数据整理，我们发现医疗资源在空间上分布不均衡，集中在重要的医疗中心，大多乡村地区的医疗资源不足。

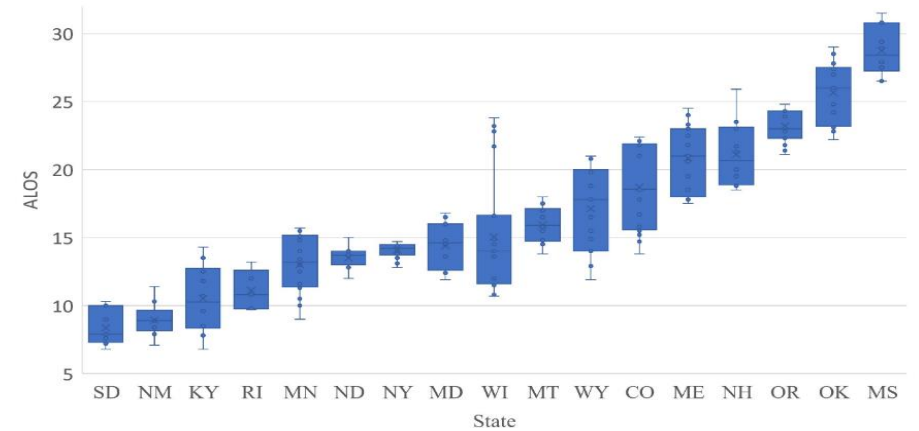
图右上：可以看到有**671**个县是没有病床或者对于新冠肺炎治疗的医疗专家的。



各州的治疗水平也明显不同，根据**19**个有数据披露的州，发现住院的病人平均在院的时间长度也不同，纽约州平均**14**天出院，而经济水平较差的密西西比州需要住院**28**天。



The 671 counties without licensed beds or CCS.



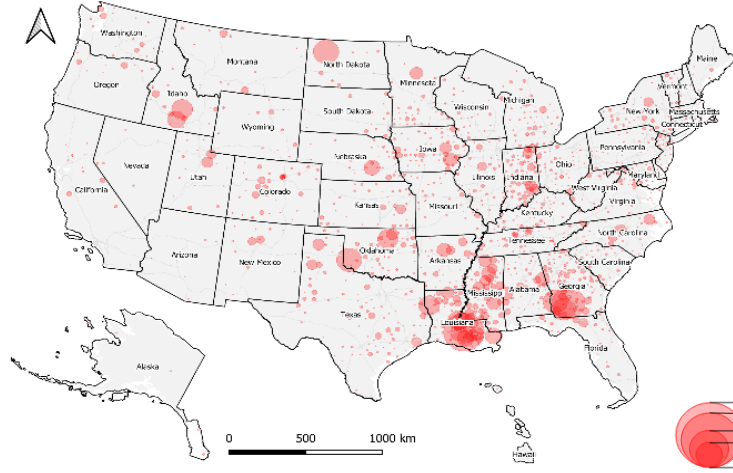
Box-plot of hospitalized ALOS among 19 states



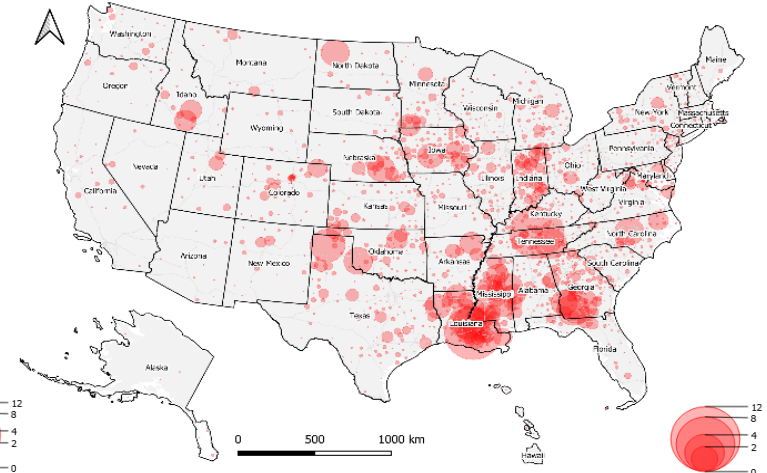
美国的公共卫生系统承载力如何？



(a) March 15, 2020



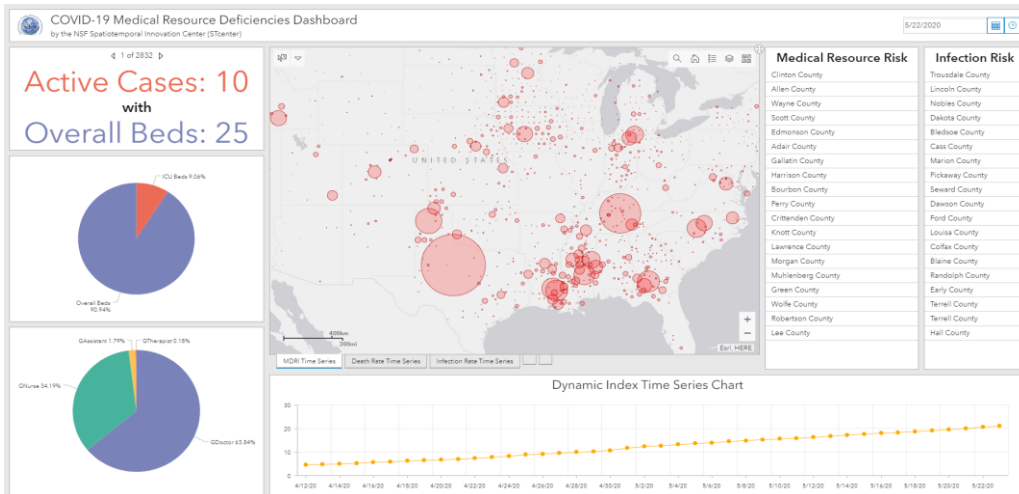
(b) April 15, 2020



(c) May 1, 2020

General MRDI trend.

$$MRDI = \frac{N_c - N_{death}}{N_{licbed} \cdot N_{CCS}}$$



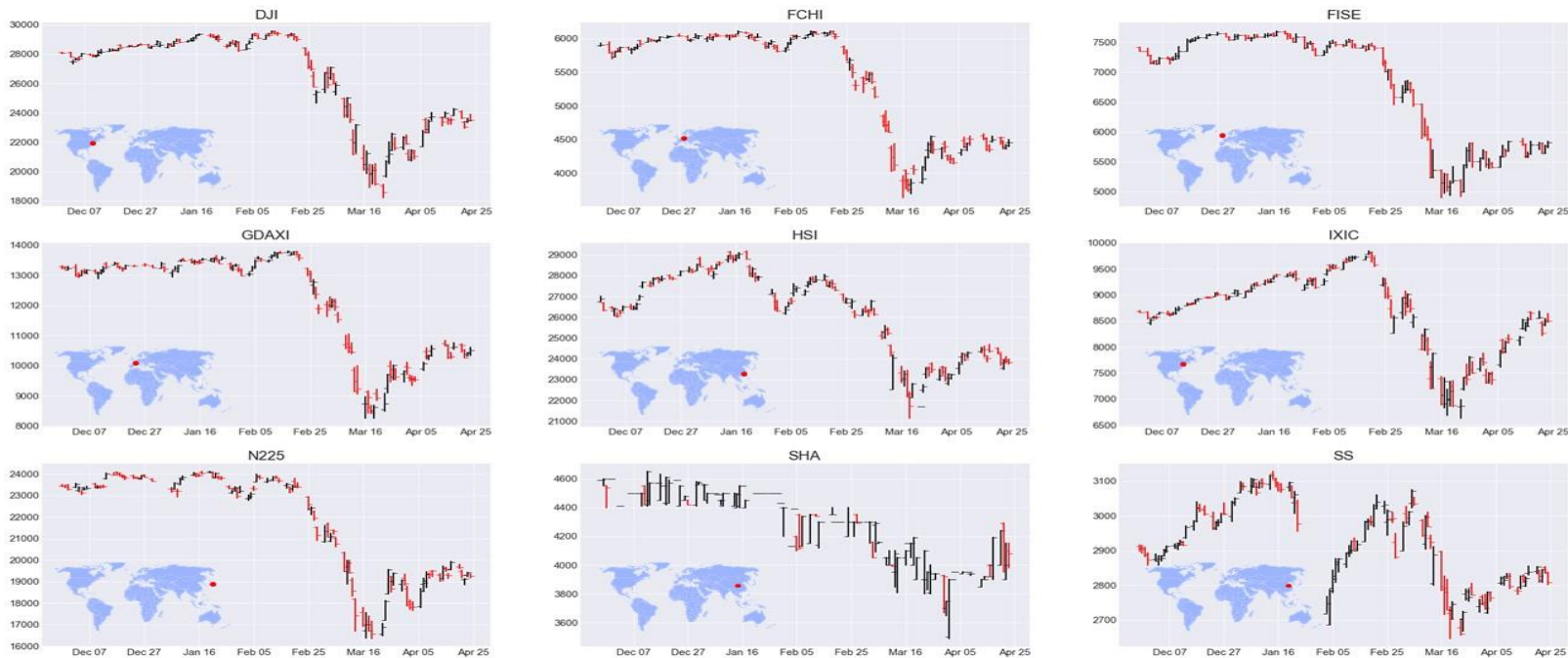
<http://mrd-dashboard.stcenter.net/>

Spatiotemporal visualization interface based on ArcGIS Dashboards.

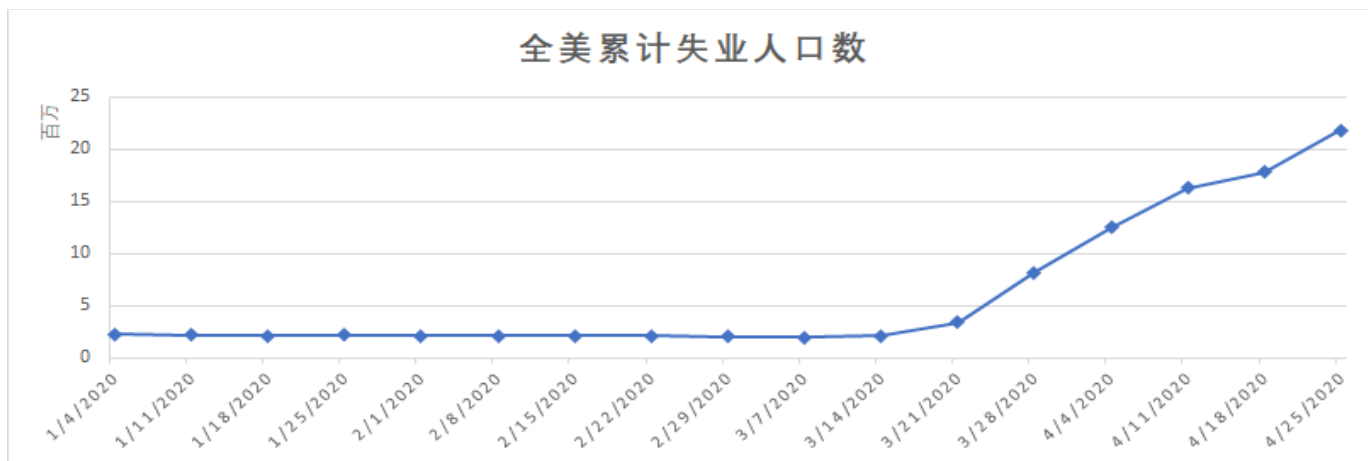
引入动态的每日确诊死亡人数，用医疗资源数相除，得到医疗资源动态承载力指数。可见医疗资源不发达地区的严重程度强于纽约加州等疫情大爆发的区域。



疫情对经济有什么影响？



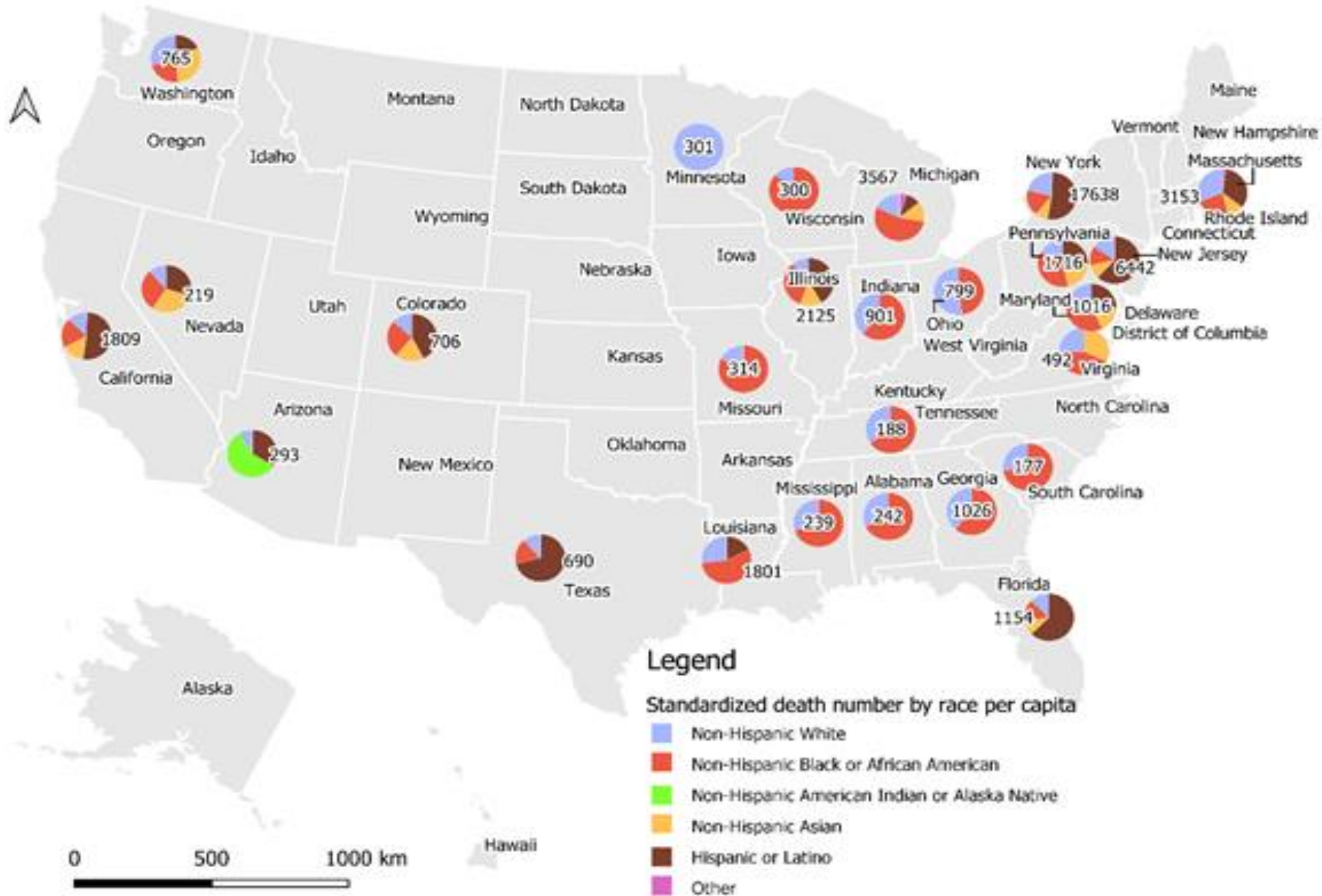
全球股票市场呈现的时空模式与病毒传播高度相关



美国累积失业人口变化



新冠病毒是否针对特定的人群?



各州每个种族死亡数与人口数的比值，可见不同族裔受到影响显著不同。

Sha et al., 2020



新冠病毒是否针对特定的人群?

Variable	Coefficient	Std. Error	Probability
Elderly Rate	-12.6535	5.29928	0.02364
Educational Attainment	-9.96245	5.2992	0.05011
Poverty Rate	17.0477	5.99688	0.00447
Income	0.3127	0.137774	0.02320
Spatial Lag	0.591188	0.0487105	0.00000
Constant	4.13026	5.59176	0.00233
R-squared	0.577802		

以麻州的城市为例，利用空间滞后回归模型，分析社会经济指标与患病率的关系。结果表明：老龄率和接受高等教育的比例与患病率存在负相关性，贫困率与患病率存在较强正相关性。



Outline: 提纲

1. Introduction & Background: 研究背景
2. Computing Infrastructure: 计算平台
3. Data Collection & Sharing: 数据收集与共享
4. Spatiotemporal Pattern Analytics: 时空特性分析
5. Summary: 总结
6. Acknowledgements: 致谢



总结：时空特性

1. 疾病传播的方式。
2. 社会经济差距和脆弱性。
3. 流动性与社会距离。
4. ICU和呼吸机等医疗保健设施的可用性。
5. 从暴发城市和地区的相似气候带（从武汉、伊朗、新加坡、巴西、印度、俄罗斯、意大利到西雅图和纽约）来看，气候与疫情爆发有一定联系、但并不密切。
6. 经济问题，例如消费者需求变化、供应链中断、（失业）就业模式。
7. 政策、新闻或社会情绪变化与疫情爆发严重程度之间的关系是病毒长期控制和约束以及人类社会设法与病毒共存的关键。
8. 平衡开放数据和隐私保护策略。



总结：反思与观点

1. 应对政策和行政措施
2. 地球上的生命
3. 自然和人力改造的平衡
4. 政治、人道和对全球紧急情况快速反应
5. 开放的世界和地球村



下一步研究计划

- 联合研究、数据共享、有针对性提供服务
- 继续跟踪、分析和识别问题
- 扩展到西班牙裔和非裔美国人等社区，提高他们的防范能力
- 调查大流行后的应变能力
- 重新思考时空研究如何帮助改善对全国乃至全球紧急情况反应



Outline: 提纲

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4. Spatiotemporal Pattern Analytics: 时空特性分析
5. Summary: 总结
6. Acknowledgements: 致谢



致谢/Acknowledgements

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- 各个工作小组的大力支持
- Harvard CVT（冠状病毒可视化小组）



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- We give our special thanks to our NSF program project directors, Rita Rodriguez, Dmitri Perkins, Behrooz Shirazi, our evaluators Donald Price & David Meyer, IAB chairs Lynn Usery (past chair) and Myra Bambacus, and Daniel Duffy
- All our partners



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7. Yu, M.; Bambacus, M.; Cervone, G.; Clarke, K.; Duffy, D.; Huang, Q.; Li, J.; Li, W.; Li, Z.; Liu, Q. Spatiotemporal event detection: a review. International Journal of Digital Earth 2020, 1-27.
8. Yang, C.; Wu, H.; Huang, Q.; Li, Z.; Li, J. Using spatial principles to optimize distributed computing for enabling the physical science discoveries. Proceedings of the National Academy of Sciences 2011, 108, 5498-5503.



Thank you: 谢谢

Question & Comments?

Points of contact:

Phil Yang, cyang3@gmu.edu



加入疫情研究群与注册系列讲座

加入疫情研究群



在线系列讲座注册

